VICTOR LEFEBURE
AUTHOR OF 'THE RIDDLE OF THE RHINE

SCIENTIFIC DISARMAMENT

A TREATMENT
BASED ON THE FACTS OF
ARMAMENT

Mundanus Ltd
VICTOR GOLLANCZ PUBLISHER
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With Introductions by
THE ARCHBISHOP OF YORK
MISS JANE ADDAMS
HIS EXCELLENCY COUNT BERNSTORFF
SENATOR L. DE BROUCKERE
VISCOUNT CECIL
PROFESSOR F. G. DONNAN, F.R.S.
THE RT. HON. D. LLOYD GEORGE, O.M., M.P.
SIR ALFRED HOPKINSON, K.C.
DR. HERBERT LEVINSTEIN
PROFESSOR GILBERT MURRAY
ADMIRAL SIR HERBERT RICHMOND, K.C.B.
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PUBLISHER'S FOREWORD

There are several things which are unusual about this book. The format is (for England) unusual: the price is unusual: and the fact that it is introduced to the public by no less than fifteen "leaders of opinion" is unusual. Since there is no editor to explain these things the publisher may, perhaps, be forgiven for taking his place.

The most unusual thing of all is, of course, the text itself. It sets forth the results of quite the most important piece of constructive thinking which (so it seems to me) has yet been given to the question of disarmament. The unique character of the book is suggested by its title : here, for the first time, are set out the rudiments of a *science* of disarmament—the bricks with which the art of statesmanship may build.

And because Major Lefebure approaches his subject scientifically he gives us more hope than we have ever had before. After reading his book we need no longer talk vaguely about the desirability of disarmament, or hopelessly because we know that total disarmament is at present quite impracticable: we are for the first time able to say " Let us prohibit A, limit B in this respect or that, and leave C unrestricted: such a compromise will leave each nation with armaments which they will recognise as sufficient for national safety, but will also (owing to the time-lag required for conversion and development, and to other factors) make it almost impossible for a nation to embark on war."

It has always seemed to me certain that only the most radical and uncompromising change in the economic structure of the world will give our children's children, after perhaps centuries of misery, the kind of civilisation in which war will be for ever impossible. Now Major Lefebure shows us the one chance in a hundred of preventing war within the present system : if it were one chance in ten million we should be contemptible did we not give it the most anxious consideration.

Feeling this about the book I also felt that to publish it as such books are ordinarily published would be frivolous and irresponsible.

Scientific Disarmament is nearly twice as long as the average modern novel : it is unsubsidised : the topic is what is known as a " serious " one : and the manner in which it is treated holds out to the reader no hope of light amusement. The current practice is to print a small edition of such a work on " good " paper, to bind it in the best cloth with gilt lettering, and to fix the price at about fifteen shillings. When a book is of real importance, there can be only one excuse for thus limiting its sale to the comparatively rich—that a lower price is economically impossible.

I do not believe it : if it is true—if four or five thousand people are indeed unwilling to buy a book such as this for the price of 5s.—then Major Lefebure is wasting his work, for he is addressing a people careless, with a shameful light-heartedness, of their own impending doom.

This same consideration which led to the lowering of price—the feeling that here was a book which must be given its chance of being widely read—suggested also the series of introductions which follow. If we refrain, Major Lefebure and I, from expressing our thanks to the writers, it is because gratitude in connection with such a theme would be an impertinence.

V. G.

FOREWORDS

THE ARCHBISHOP OF YORK:

I am glad to write a few words in commendation of this book. It is a careful study of a subject which is both vitally important and extremely difficult. There is a danger that harm may be done to the cause of peace by the lack of idealism among those who know and a lack of knowledge among idealists. This book is an expression of their combination and deserves a wide public.

MISS JANE ADDAMS:

The book is such a scientific study of the development of armaments in the world order as may well suggest the method of approach which must be preliminary to new abolition.

HIS EXCELLENCY COUNT BERNSTORFF:

This book is of great interest as a new approach to the problem of disarmament—a problem which should be studied from all angles and by all nations before the meeting of the Disarmament Conference.

SENATOR DE BROUCKERE:

Vous me demandez quelques mots de présentation pour votre ouvrage : il est de ceux qui se présentent d'eux même ! Je l'ai lu à mon premier moment de loisir, et sa lecture m'a intéressé plus que je ne pourrais dire. Vous nous avez apporté, pour la première fois je pense, une démonstration vraiment documentée de l'importance en cette matière de ce " facteur temps," de ce " Conversion lag " qu'il est tout à fait essentiel de prendre constamment en considération.

J'espère que tous ceux qui auront—prochainement, je veux le souhaiter—le redoutable honneur de rédiger la convention de réduction des armements vous lisent. Ils auront l'avis d'un expert dont la science égale la bonne volonté, et qui mérite ainsi doublement d'être écouté.

VISCOUNT CECIL:

It is to be hoped that all who are interested in Disarmament will read this book for it attacks the problem from a new angle. Discussions have till now proceeded from the political point of view. We have generally assumed that the way of achieving disarmament is by reduction either of numbers or of cost, or both. The main difficulties considered have been the extent to which reduction would be accepted and the method of ensuring that a reduction once accepted would be carried out. Round these central difficulties have raged the controversies about conscription, supervision, security, and the rest. But another and equally essential matter has been largely overlooked which our author calls disarmament of type. Granted a scheme of disarmament resting on numbers and cost is in force it will still be possible to renew competition with all its attendant evils by improvement of type, by better methods of manufacture, by new inventions, especially perhaps in the domain of chemical warfare. Here is a formidable problem. How will it advantage the world if the armies, navies and air forces are reduced both in number and cost, both in personnel and material, if by the

perverse ingenuity of man those smaller forces can deal death and destruction more effectively than ever before? The case made in these pages is a very strong one and the picture drawn in cold and scientific language of the certain consequences of air warfare, for instance, even as it exists to-day and still more as it may easily be to-morrow, are literally terrific. The question calls for close and immediate consideration, the more so since we are told that remedies are practical and available if only the nations have the courage to put them into force.

PROFESSOR F. G. DONNAN, F.R.S.:

Major Lefebure has written a very noteworthy and valuable book. It could only have been written in virtue of that unusual combination of scientific equipment and armament knowledge and experience which he possesses.

Probably the most important feature of the book is the exposure for the first time, of the organic connection between the development of new armament types, the new agencies of war, and the main structure of disarmament. If the latter is to be real, this problem must be faced, and the co-operation of science in some form or other will prove essential. However much the author's proposals may be criticised or remoulded, the fact remains that his book establishes the existence of a problem to which the scientific world cannot remain indifferent if peace is to be stabilised through disarmament.

This work is unusually important and I wish it all success.

THE RT. HON. D. LLOYD GEORGE, O.M., M.P.:

Some of the chapters of *Scientific Disarmament* bring back vividly to my mind the problems which confronted us at the Ministry of Munitions in the early part of the War. We did not shirk the task of arming in those days, nor must we shirk to-day the even harder task of disarming. We must apply the same expert knowledge and technical ability to the cutting down of armaments as we did to the building up of that gigantic war weapon in 1914–18. If we do not, then woe betide Europe!

SIR ALFRED HOPKINSON, K.C.:

The subject of Major Lefebure's work and his manner of treating it, are of the greatest importance and value at the present time. One part of it has already had special consideration by the International Law Association. In 1921 a committee (of which Mr. Justice Peterson was first Chairman) was appointed by the International Law Association to consider the question of "Chemical Warfare."

The attention of the committee was almost wholly directed to the question of the use of "poison gas" in war. A careful report was made and presented at the meeting of the Association at Buenos Aires in 1923. The committee had the advantage of the expert knowledge, such as the late Sir Edward Thorpe and Major Lefebure possessed. What was needed and is still needed is not vague general talk about the importance of disarmament or the direction of attention to political considerations. It is the "technical background" of the subject that should be worked out in detail to see what is possible. It needs scientific treatment by people who have devoted attention to the practical difficulties and really understand them.

The work that has been done by Major Lefebure and the conclusions reached after careful study ought to be carefully read by all who wish to see the question of disarmament effectively and wisely dealt with.

DR. HERBERT LEVINSTEIN:

I know of no one so well equipped as Major Lefebure to deal with the subject of this book. He received his scientific training under that great chemist Sir William Ramsay. He was soon in the war acquiring with distinction the art and practice of modern arms on active service. After the war there were few officers better known in our chemical warfare Service, or in those of our Allies. Since then he has had experience of factory conditions. The result is a treatise on disarmament distinguished by originality, by clear and courageous thinking, and by knowledge. Effective disarmament cannot, many of us think, be achieved by selecting somewhat haphazardly this weapon or that arm for limitation or prohibition. The author deals with disarmament logically as an applied science. The principles of this science we must study and when they are accepted as true, all nations can be fairly asked to apply them, thus leaving to the Courts the last word in settling international disputes. This point of view and object will meet with wide approval. In my opinion Major Lefebure has rendered a great service by his statement and definition of the problem, by examining in detail many of the difficulties, and by giving a clear and acceptable outline of the method to be followed.

PROFESSOR GILBERT MURRAY:

This book constitutes a definite and most important contribution to the cause of Disarmament.

The subject has, of course, both a political and a technical side. The first and most obvious problem is to induce the nations, with their Governments, Admiralties and War Offices, to agree in principle to a general " Reduction and Limitation of Armaments by International Agreement," and to be willing to carry out the agreement when made. The second lies always in the background but always present : Suppose they do agree, can the thing be really done ? Can we all disarm in such a way as to establish security and preclude the danger of sudden attack ?

Everyone who has had experience of this movement knows how, at a certain stage of the discussion, the defenders of the old indefensible system of competitive armaments, take refuge in the argument that effective Disarmament is technically impossible. " How can you guard against new inventions ? Against the sudden transformation of commercial aeroplanes into bombers, of chemical and engineering works into poison-gas factories and arsenals, and the like ? What security is ever possible except the fear of reprisals ? Therefore let us double our means of attack and let them know that if they destroy London we will destroy their capital the next night ! "

Addressing himself strictly to this technical problem, Major Lefebure shows with masterly knowledge and patience that there is an adequate answer to every one of these objections and that, as a technical problem, Security by Disarmament is not insoluble. The thing can be done if the nations wish to do it. The way is open if we can produce the will.

ADMIRAL SIR HERBERT RICHMOND, K.C.B.:

This book, in my opinion, furnishes a new approach to the problem of disarmament which merits serious attention. The problem—call it disarmament or reduction of armaments—is one that requires investigation by methods in no way different from that used in the ordinary processes of research in every field. Huxley's saying that the free employment of reason in accordance with scientific method is the sole method of reaching truth is itself a truth as absolute in armaments as in biology. The processes of thought by which Mr. Lefebure approaches the problem fully merit the description of the scientific method.

Even if, in spite of a want of weapons, or of a promise of obtaining a supply at some near or more remote time, nations will again fight, this fact—if fact it be—in no way invalidates the course of reasoning by which Mr. Lefebure argues that a reduction of armaments lies within the range of practical, that is, political and physical, possibility.

To the distinction which has already been recognised as essential between the quantitative and the qualitative—quantity or type—Mr. Lefebure adds another, which appears to have received a less general, if any, recognition, i.e., that between existing instruments of warfare and the "new agencies" which either are coming, or may come, into existence. "As science and its industrial applications progress," he reminds us, new forms of armament arise, capable of rapid production : so to neutralise this we should consider the means of controlling the evolution of new types (p. 113) ; and again, "It is a farce to call off the armament race in the old weapons and leave it in full blast for the newer weapons which will make them obsolete." We need not here argue whether or not the older weapons will be rendered obsolete : whether we agree or disagree with this opinion we have an ample stimulus to pursue this investigation if only for the purposes of world economy.

A very particular attention is recommended to the chapters dealing with the new agencies in war and their influence upon disarmament. These furnish food for most serious thought and discussion. In those new agencies lie some of the most fruitful causes of suspicion and of fear, and consequently of increase of armaments and increase in the burdens which lie upon the backs of the citizens of the world. To any serious thinker there can hardly be a doubt that instability of type is a definite hindrance to the reduction of armaments.

The treatment of the aircraft question is a valuable contribution to a problem which has been one of the chief obstacles in the path of disarmament.

LORD RIDDELL:

The title of this book should be "Will Science Destroy Civilization?" Mr. Lefebure, the author, gives a graphic survey of modern armaments—guns, shells, poison gas, tanks, machine-guns, microbes, rifles, aeroplanes and the rest. It is a fascinating gruesome story, which makes the flesh creep. He tells us that these atrocious things are being made in most civilized countries, and that every year adds some new horror to the catalogue. He tells us also that proposals for disarmament centre mostly on the old-fashioned items, and that the new and more deadly ones almost escape attention. Poison gas, in its many monstrous

varieties, seems to be a favourite and prolific subject with the best inventive brains of the chemical world. While the unsuspecting man in the street is going about his business, the experts are compounding horrible gases, designed to destroy and mutilate both combatants and non-combatants. What a prospect ! We live in a strange illogical world. By international agreement supplies of cocaine, heroin and other similar drugs are strictly limited, apparently for the protection of a few thousand drug addicts. On the other hand, there seems to be no restriction on the manufacture of poison gas. As far as I can understand, Mr. Lefebure relies for protection on the inevitable delays that must occur before implements of war, or at any rate the most fearsome of them, can be brought into full blast. This is not very reassuring when one remembers what terrible injuries might be inflicted by quite infinitesimal doses. But perhaps Mr. Lefebure's main object is to furnish a more or less detailed account of the armament situation, so as to warn the world of the dangers that await it unless it chooses the path of peace. If that is his object, he has certainly achieved it. To most people the contents of " Scientific Disarmament " will come as a revelation. Obviously we are sitting on a box of dynamite. The question is, what can be done to protect civilization ? Mr. Lefebure has rendered an international service in producing this book. Whether he has named it rightly or wrongly does not matter. Nor does it matter whether one agrees with the adequacy of his remedy. He discloses the facts. If is for the individual citizen to bring pressure to bear upon his or her rulers to take practical steps to save the world.

FIELD-MARSHAL SIR WILLIAM ROBERTSON, G.C.B. :

Besides being a welcome attempt to show how so-called " disarmament " could be expedited and the peace of the world be thereby the better ensured, this book has a distinctive feature of its own in that it approaches the problem to be solved from a standpoint not usually employed. It contends, and not without justification, that past efforts to bring about a reduction in armaments have been too much concerned with political and economic difficulties and obstacles and too little with technical and scientific considerations, the result being that the thorough examination of the real question at issue has been sidetracked and never yet reached.

Starting with the premise that the object which " disarmament " should serve is not only to lessen the temptation to go to war but also to afford time for the continuance of peaceful negotiations should war raise its head, the author proceeds to examine the time-periods involved in the production of armaments and other kinds of war material, and in the many other operations which have necessarily to be undertaken when passing from a disarmed condition to one admitting of a violation of peace. The main conclusion he draws from these investigations is that, if dealt with from the basis of " armament-fact " and not, as previously, mainly in a welter of political controversy, disarmament will emerge as a perfectly feasible goal, and, given the introduction of suitable measures for limiting the manufacture of certain elements of armament, such a situation could be created as would render it

impossible for any nation suddenly to rush into war and impose its will upon another by force of arms.

This is a bold assertion to make, and although supported by reliable evidence it may not satisfy those who think that " disarmament " can never be regarded as an adequate security against war unless preceded by the cultivation of a less suspicious and selfish spirit in the conduct of international affairs than that to which the world has hitherto been accustomed. On the other hand this new spirit, which we may hope is now gradually appearing, must naturally be of slow growth, and therefore there is the greater need in the meantime for considering and as far as possible adopting all such measures of disarmament as will tend to make entry into war more difficult.

Major Lefebure's views regarding these measures and their dependence upon organic chemistry are of special interest because of his connection with chemical research and industry both before and after the war, and his long experience of chemical warfare with the allied armies in France. The facts upon which he bases his recommendations are both comprehensive and informative, and he performs a public service in bringing them to notice. It is to be hoped that they will receive the attention of a wide circle of readers.

GENERAL THE RT. HON. J. C. SMUTS:

Disarmament is to-day undoubtedly the most important of all international issues. National viewpoints and prejudices however make a reasonable solution more difficult, and the results of the Preparatory Disarmament Commission have been disappointingly meagre. In this unfavourable atmosphere the coming Disarmament Conference may lead to a dangerous situation for the League, and eventually for the peace of the world.

Major Lefebure's book breaks new ground, and I specially welcome this scientific study of Armament and Disarmament, apart from the political implications of the subject. Here, just as in the Reparation question, the scientific expert may succeed in finding clues where the politician is baffled and powerless. The demand for security, for instance, appears in a new light when the technique of disarmament, and especially the time factor involved in armament, are considered.

This study is a distinct contribution to the consideration of this thorny subject and it is deserving of careful consideration.

MR. H. G. WELLS:

Scientific Disarmament is the most convenient and able account of the present state of world armament in existence. It is full of clear and special knowledge. Everyone interested in the prevention of war should read it and all those who write and talk about the problem of world peace should be compelled to read it. The proposals of Mr. Lefebure are sane and acceptable. He realizes clearly that States will only go to war when there is a reasonable hope of conclusive victory and his insistence upon the value of relative disarmament in causing delay and giving time for second thoughts to become effective in a phase of tension, is admirably sustained. He puts the idea of a " conversion lag " in a form that has made me reconsider my general scepticism about the value of disarmament proposals. His book is not a book of discussion merely. It is an exact, orderly and vivid summary of contemporary realities.

AUTHOR'S FOREWORD

Is it illogical or disloyal for technical men who have fostered armament in a previous national emergency, and might do so again, to take the initiative in the direction of disarmament? These questions have inevitably pursued me in writing this book, for the old loyalty to organisations and friends of the War must remain to the end. I can only say that it must be the first objective of any sane person who has seen war, to try to prevent the kind of catastrophe which engulfed the world in 1914. The deciding factor is surely this, the obligation to another generation which might again be sacrificed. If sane disarmament can assist, and if armament knowledge is an essential part, then this obligation falls upon those who possess it. Their contribution is essential, and it is because the scruples which pursued me in breaking new ground will also pursue them that I make these comments.

Many will remember my *Riddle of the Rhine*, published soon after the War, in a world still too uneasy about past dangers to give real attention to their future prevention. That book established the vital importance of chemical warfare and industry, and exposed the weakness of a disarmament which ignored the new agencies of war. The dangerous disparity between the chemical capacity of some of the Great Powers has since been removed, which is a step in the right direction, for it is not possible nor desirable that disarmament should adopt the alternative of shackling an industry so full of service.

But with the objective of organised peace, much more requires to be done. If the official disarmament effort accepts the present position of unrestricted development of new armament types, it leaves untouched the new armament race, ignoring and harbouring a growth which will eventually wither and destroy it. SCIENTIFIC DISARMAMENT exposes the nature of this growth and its organic connection with the rational structure of disarmament as a whole. In view of the somewhat natural resentment with which the *Riddle of the Rhine* was received in Germany, I hope my new book will be read there and recognised as an impartial and unbiased treatment of the subject.

Finally I must emphasise that this book is not a criticism of official efforts, with which I have the utmost sympathy, and whose difficulties I fully appreciate from personal experience in international affairs, and from knowledge based on a close study of those efforts. In the early work on a great problem of this character the official results cannot conform exactly or even largely with the true requirements. There are too many external difficulties. There must unfortunately be a gulf between agreed action and the most efficient solutions, but it is nevertheless essential to work out the scientific basis of the matter.

Disarmament is not an official act, it is an evolutionary process, and its progress and value will largely be governed by the thorough exposure of the reasoned requirements of the problem in an atmosphere which regards political difficulties as things to be overcome.

V. L.

CHAPTER I

SCIENCE OR STALEMATE

Hundreds of thousands, perhaps millions, of thinking people all over the world share the common objective of the prevention of war and the stabilisation of peace by means of a process which they call disarmament. They have anxiously watched their own national groups and official international organisations striving to obtain practical results for a decade in a manner absolutely unparalleled in the history of the world. Apart from the development of this movement and of the moral momentum behind it, which, of course, are of the utmost importance, the general feeling is one of the deepest disappointment. Practical results have been meagre, and the future is black.

This state of affairs has naturally invited and produced a widespread expression of views which, in many cases, has taken the form of books claiming to deal with the subject of disarmament It may therefore be asked why another should be added.

It is a curious thing that during the whole twelve years of international activity, of official and private publication and conference, the subject of technical disarmament, the non-political and scientific aspect, has received an amazingly small amount of informed consideration. A detailed examination of records and publications admits no other conclusion. One gets a general impression, either from surveying the whole movement or any one of its component steps, of a process starting out genuinely towards disarmament but finding initial external difficulties of a political or economic character, and diverting its energies to other solutions of the problem of peace and war, with the net result that the thorough consideration of real disarmament is sidetracked and has never yet been reached. This, of course, is a somewhat sweeping generalisation, and there are one or two notable exceptions, but the mere fact that they stand out so clearly only serves to show that the claim is substantially true.

One examines the very full records of the Washington Conference, more promising for the world than any one before or since, and in every field of armament which it touched, with the partial exception of naval matters, a position of stalemate was

reached before the real subject-matter of disarmament was explored. The same situation arises time after time in the records of the steady labours of the various disarmament commissions at Geneva. Those same records, and many others, reveal the reason underlying this unhappy situation, and they provide more than sufficient justification for the effort represented by this book.

Washington started out to control the new agencies of war and to rid the world of their terrible dangers in the future. The nations agreed to prohibit their use in war ; but they wanted to do much more, and support this prohibition by international measures during peace, by real disarmament. As soon as this point arose came stalemate. The strongest opinions were advanced with the utmost political authority that nothing could be done. New chemical weapons, it was claimed, could spring up unsuspected, miraculously, in incredibly short periods of time. Practical measures were impossible. There was no safeguard beyond reprisal and moral force. But no attempt was made, or we can learn of none, to take this problem out of the region of opinion, to consider it as a technical matter, which indeed it was ; quietly to explore all its facts and to seek a solution in terms of them. Had this been done, the idea of the sudden emerging of the new agencies to threaten a peaceful world, somewhat on the lines of an epidemic of measles, would have been exploded. It would have been realised that we were faced, not with a spontaneous phenomenon, quite uncontrollable, but with a long, steady growth involving a number of specific steps, each of which permitted effective measures of control, and the integration of which gave real hope of disarmament in the true sense.

Or again, at Geneva, in dealing with normal armament, we find the utmost confusion of opinion on technical matters of fact. The influence of national means of armament production upon security through disarmament depends entirely upon certain industrial factors, such as the time-lag required to multiply stocks and producing capacity from a given armament position. Now this is a question of fact for each form of armament. In the limit it need never rest on opinion, and in ordinary business activities it would never be allowed to do so. But in disarmament discussions we find case after case of delay and inability to arrive at a common viewpoint because the simple technical aspect was ignored just as though no background of fact existed.

In other words, one of the reasons, and perhaps the main reason, for our disappointments in the disarmament field is that we

have consistently ignored the fundamental fact that disarmament is a technical subject based on facts surrounding armament, and that we can arrive at solutions which, although they may not be adopted entirely, and may be distorted by political forces, yet represent the best possible rational foundation on which to build.

The writer has therefore started out as a student of armament to establish a range of facts which are basic in reaching rational disarmament, or at least to demonstrate that a well-organised and supported effort could reach such facts. Further, starting with sufficient real information, it is possible to proceed from first principles and establish a framework of disarmament theory, standards with which proposed measures can be compared, and on which rational schemes could be based.

On various occasions, before scientific, legal, and other societies, usually interested in peace, but sometimes in war, I have had the opportunity of exposing this special technical approach to disarmament, and it has been most striking to see how large numbers of people are waiting for an opportunity to get an intellectual grip on this problem.

The subject is new, and the danger and practice is to flounder in a maze of facts and opinions, trying, without any real guidance, to seize upon those which are reliable and significant as a basis of rational constructive disarmament effort. There is, and there can be, no general traditional background of knowledge on the matter, such as exists in most other great issues, and this book is an attempt to provide it.

Some of the great questions of technical disarmament, on the recognition and solution of which the peace of the world may depend, far from being explored, have hardly seized the minds of countless disarmament advocates greedy to absorb anything with real bearing on the question. What are the broad essentials of the disarmament scheme ? How should we decide the reduced quantities of national armaments and their international ratios in order to afford substantial security ? Is it only a question of compromise or of guesswork, or is it governed by reasoned principles ? If so, what are they ? What is the bearing of producing capacity as distinct from equipment or stock of armament ? What are the characteristics of armament production which govern disarmament requirements ? How far does the present organisation of armament production present an obstacle to disarmament, and what principles should govern its reorganisation ? What bearing has the question of armament type upon schemes

to stabilise quantity? Type brings in the whole question of armament development, the new agencies of war, how they develop. What are the facts of this process, how far do they nullify the effects of disarmament at any given time, and how can their control be brought into the scheme? In the answers to these and similar questions we have the whole structure of technical disarmament. Without them we can hardly claim to hold intelligent views upon this great question, whatever our aspirations may be.

The following situation has developed on a number of occasions during the last ten years in the great international disarmament organisations. The political heads of the nations concerned, say through the Council of the League of Nations, have agreed on certain objectives, and have accordingly framed terms of reference for the so-called technical commissions, to enable the latter to produce actual schemes giving effect to the agreed principles. The commissions have then got to work, and, after several months, they have reached a position of stalemate because of a very wide difference of opinion amongst their members on certain critical points. In one case they could not agree as to whether new weapons could emerge from chemical factories almost instantaneously, or whether it was a long-time process; and in another case some representatives claimed that bulk shell production could occur in a few weeks, whereas others said it was a matter of many months. But such points are not matters of opinion; they are ascertainable fact. The sum total of delay introduced by the frequent development of similar situations has in my opinion retarded practical disarmament by some years.

The claim put forward is that such situations would not have remained as permanent obstacles if there had existed a general background of essential knowledge on the requirements of technical disarmament, such as we find on other great matters of public interest, as, for example, education or health. There is no mystery and no particular difficulty in the subject of real disarmament as such, but we have been defeated by the sharp incidence of the problem upon a world which has not digested it. There is very little secrecy about the proceedings and deliberations of the League of Nations. The frankness and volume of their publications is unprecedented. The trouble is the absence of a sufficient background of solid knowledge on the matter by the intelligent public, preventing any widespread appreciation of what is going on, of the obstacles and difficulties,

the absence of any quick response and formative influence through public opinion.

It would be a calamity if in the space of a year or so we were asked to endorse a series of vital practical measures of disarmament to ensure the peace of the world without having developed a far wider appreciation of the intellectual requirements of the problem. This book cannot hope to fulfil such a need ; it is only a small contribution, but it is symptomatic of the work which should be pursued from now and onwards if valuable results are to be obtained. Technical disarmament must be studied as distinct from the important but subsidiary political problems which have surrounded and submerged it.

We started out to stabilise peace through disarmament, and we are, in effect, gradually abandoning this objective on the tacit but entirely unproved assumption that it is technically impracticable. The result is a further diffusion of effort in which the attention of the thinking world is diverted to what we may call " single measure " solutions of the problem, universal panaceas. Thus there have been a number of suggestions, supported by voluminous publication, roughly on the following lines. The nations will never disarm, the general problem is insoluble, or, even if they do, they will not honour their undertakings, and we must therefore have an international police force. Or, again, the problem is so difficult that we will ignore actual disarmament except in the case of one or two special fields, such as naval matters ; we will not press unduly for a really balanced scheme and drastic reductions, but will compensate the smaller and less industrial nations by covenants on such matters as financial assistance. Or, again, we have the idea of mineral sanctions, championed by Sir Thomas Holland, based on the fact that no nation is self-sufficient as regards the minerals required for war, and an outlawed nation would be deprived of certain essential products by its lawful neighbours.

All such schemes are subject to the gravest reasoned criticism, which we cannot develop here, when considered as isolated measures. They all contain some element of value as part of a general scheme. But they are all beside the point as alternatives to real disarmament until at some point or other in peace organisation a really thorough and informed exploration of technical disarmament has been carried out. That is not the position to-day. Much good work has been done, and there is no intention of disparaging, for example, the efforts of the League. But the

fact remains that either through lack of equipment or opportunity or the correct terms of reference, or through political considerations preventing straight technical thinking, no effort has yet been made the results of which could be regarded as intellectually satisfying the problem of technical disarmament, either by producing an adequate scheme or by pronouncing it as insoluble.

This book does not provide a complete scheme, nor does it attempt to do so, but it indicates a whole range of facts, and of conclusions therefrom, on which the logical requirements could be built up, which have been largely ignored or sidetracked in the past. It certainly allows the conclusion that an effective condition of technical disarmament is a possibility.

It can be said without exaggeration that technical disarmament has been the Cinderella of the whole family of peace problems, whereas it is really one of its chief members, and if we do not bring it out of its retirement for the most open and thorough inspection the world may well be heading for a quite unnecessary disaster.

CHAPTER II

THE NATURE OF THE PROBLEM

Armament and Disarmament as Applied Science : Three Fundamental Questions : The Meaning of Disarmament : Is Disarmament Feasible? : What are the Reasoned Requirements ?

ARMAMENT AND DISARMAMENT AS APPLIED SCIENCE

The study of armament is a branch of applied science. Although not such a sharply defined example as chemical industry, based on chemical science, or psycho-analysis, based on mental science, it possesses all the required characteristics. It has a specific technical objective, the operation of war, and, in reaching towards it, armament employs research activities in the different sciences which feed it, half-scale and large-scale investigations of a technical nature, and highly scientific processes of manufacture and application. The best analogy would perhaps be found in medicine, which is fairly regarded as a branch of applied science, even though it finds its roots and evolves its facts and methods of progress from a wide range of pure sciences.

Strictly speaking, disarmament is one of the problems of armament. The latter is an activity or development process which strives to build up and increase the quantity and efficiency of the methods of making war by violent means. Disarmament can be regarded somewhat loosely as the converse process—the reduction and reorganisation of armament to such a point that only certain types of hostilities are possible, and others are prevented. It follows that the scientific and technical characteristics of armament must to a certain extent govern disarmament, and be taken into consideration in dealing with it. Building science controls the erection of a great building, and cannot be ignored without fatal results in its demolition or structural reorganisation. This is a fairly close parallel, but peace provides singularly few, for the simple reason that we cannot afford to create huge and complex economic or industrial systems with the possibility that sooner or later they may have to be rooted out as vicious growths.

The broad question of disarmament is receiving the consideration of the official world, but, although the physical, moral, and

economic well-being of every individual may well be governed in the near or distant future by such deliberations, it can be said quite fairly that, while the public has been saturated with the need of, the reasons for, and the obstacles preventing disarmament, they have remained in wide ignorance of the real facts and requirements of disarmament as a technical matter in operation. We therefore begin our investigation from rock bottom and from first principles, endeavouring to make no assumptions and to rest on no opinions which are not supported by ascertainable facts which in the main must be drawn from the subject of armament itself.

THREE FUNDAMENTAL QUESTIONS

We are really faced with three fundamental questions. What do we mean by disarmament? Is it a feasible thing; are we chasing a will-o'-the-wisp, something which is denied on scientific grounds, or can it be made practical and effective in terms of the most honest technical thought? What are the reasoned requirements of disarmament in operation? If these three questions could be answered solidly to the satisfaction of thinking people, and the answers could be brought to their knowledge in a world-wide sense, the cause of peace through disarmament would have received the final impetus from which it could never turn back.

THE MEANING OF DISARMAMENT

There is no need to embark on a philosophical discourse on all its moral, economic, and political aspects. We are concerned with the technical field, and simply need a definition which we can adopt as a common background for these discussions. Let us clear the ground before attempting to define. Somewhere in the definition there must be reference to the ultimate objective, the prevention of war. What is war, for our purposes?

War is a term which, in the absence of definition, can carry many interpretations. For our purpose I wish to imply a special type of large-scale, organised hostilities between civilised nations. Small colonial expeditions, police work, frontier defence against backward races, and many past wars, are thereby excluded from my scope, lacking, as they do, in many directions, the essential characteristics of the last great conflict. Although, on the broadest

lines, the subject is technical, yet we are not dealing with mathematical conceptions. The super-critic might say that if a disarmament scheme claims to prevent war, it must be tested and judged by its capacity to prevent hostilities of any sort, which, of course, is not my viewpoint. It is a question of degree, requires a sense of proportion, and the big problem before us to-day is to prevent the recurrence of an outbreak such as occurred in 1914, or of a war between two powers sufficiently important to lead to such an event. War is too often regarded as an activity which, so to speak, was introduced with man, the outcome of things so deep rooted within him as to be inevitable. This is a dangerous hypothesis, because it deadens resistance; it is a sweeping and shallow view, inaccurate and misleading. Paleolithic man fought his fellows, but he did not make war, which, the organised aggression of groups or communities, could not precede their development. Historical evidence would probably place war as emerging from human strife some twenty thousand years ago, and even to-day there exist primitive and "backward" peoples—Australian aborigines—who know nothing of it. Therefore, in referring to the prevention of war, we are not concerned at the moment with some philosophical conception of the elimination of all violence from the world, but with an intensely practical view based on expediency, the very urgent need of the near and middle future to prevent the development and occurrence of great world conflicts and of national hostilities from which they emerge.

Disarmament thus becomes a process or a series of operations directed towards the reduction of existing armament and the prevention of future growth, and, in general, the reorganisation of armament in such a manner as to prevent war as we have defined it, while permitting those forms of hostilities to which we have referred, which the world unfortunately, but quite definitely, must contemplate at the moment.

IS DISARMAMENT FEASIBLE?

There is no direct approach to this question, and no means of answering it without the patient investigation which arises from our third question. Let us ignore all the answers which have been given to this question on moral, political, and similar grounds. We are not interested in the idea that, even if a sound technical scheme were devised, the evil intentions of nations would make

them evade it. It may well be that such a scheme could be made fool-proof, whatever intentions might exist. Nor can we listen to the claim that racial and political difficulties will prove insuperable, for their strength will remain an unknown quantity until the security obtainable through real disarmament has been established. This, of course, is the fallacy of the cry of "Arbitration, security, and disarmament," one after the other, in that order, a matter to which we refer later, and which Lord Cecil clearly exposed in the assembly at Geneva this year.

In any case, all comments on the feasibility of disarmament, on any ground outside the more narrow technical field, are beside the point until the world has completed the task of exploring the means of disarmament to which it set its hand some twelve years ago. So much for external matters; but how can we answer the question within its proper but more narrow technical limits?

The real answer is in the nature of a judgment which must be made after examining all the reasoned disarmament measures which can be brought forward in such an investigation as we are pursuing. There is no single measure on which the answer will depend. It has been a common fallacy and obstacle in disarmament to judge each measure brought forward by its own powers, alone and unaided, to solve the problem. One of the most important features which our investigation will demonstrate is the constant interlocking of the possible measures in different fields of armament, so that the whole scheme offers much more security than the simple sum of the individual measures. We are therefore concerned with a judgment which can only be made after every aspect has been explored. At that point the measure of risk can be estimated, and it is because such a judgment is the individual concern of every thinking person that it should not be left for obscure official decision, but brought into the light of a formed and formative international public opinion.

WHAT ARE THE REASONED REQUIREMENTS?

We are not proposing to examine the detailed answer to this question at this point. Indeed, it is the whole subject to which this book is a contribution. But let us see what course we must pursue to reach an answer. We should first examine an idea on which the whole subject is based.

Disarmament cannot be considered in a vacuum, regardless of other methods of operating international affairs. We might, for

example, reduce the armaments of the world to vanishing point, but in the absence of other methods of settling disputes the result would simply be to postpone war and not to prevent it. At some time when acute differences broke out between nations the armament race would begin afresh. Indeed, this is the position which arose in Europe in the middle and latter part of the first half of the nineteenth century. Europe was exhausted by the Napoleonic wars, the Industrial Revolution was making old forms of armament obsolete, and there was a pause, in which, compared with later years, the armament race was forgotten. This, at any rate, was true in the matter of European land armaments, which in the last half of the century acquired such colossal proportions. But no advantage was taken of this halt, no new method introduced for the settlement of disputes, and in due course great wars emerged, reaching a climax in the events which followed 1914.

In other words, whatever the moral and economic value of armament reduction, it alone is not disarmament in the sense in which we employ the term, nor consistent with its great purpose. Disarmament must operate side by side with peaceful methods of settlement of national disputes, and presupposes their existence.

It is not our task to examine the international organisation for peaceful settlement which is in process of development. We need only note that through the League of Nations, the Pact of Paris, the International Court of Justice, and allied institutions, the nations are now becoming increasingly wedded to this form of action. The duty of disarmament thus becomes clear, and it is to prevent war breaking out as an alternative method to peaceful settlement, thus destroying, at least for the time being, an organisation of inestimable value which has been laboriously created. It must not only reduce the incentive and the chances of war, but quite definitely gain time and a breathing-space for peaceful methods, should war raise its head as an imminent, ruthless, and outlawed activity. All the efforts of technical disarmament must be directed to this objective. Every step in general reduction will remove some measure of incentive and opportunity, but it will later be seen that reduction alone is not sufficient to fulfil the narrower but most important disarmament objective, the enforced breathing-space for the mechanism of arbitration and peaceful settlement.

This at once introduces our first broad conclusion. We visualise a disarmed world and a powerful nation urged towards war by strong internal impulse. At that point it is of the utmost

importance that such a nation should not be able physically to impose its will upon another, brushing aside methods of peaceful settlement by which it was bound. If we can so organise armament that large-scale hostilities cannot occur without extensive preparations over long periods, the purpose of disarmament will have been served. The first essential requirement of disarmament is to create what we may term an inert period of preparation, blocking any nation determined to break the peace. What is that period to be ? Can we say that if disarmament cannot check the outbreak and pursuance of successful large-scale hostilities for a period of two years, or six months, it is useless ? Clearly there is no such exact standard, for we do not yet know the final organisation for arbitration and peaceful settlement, nor its speed in operation. Again, it will be seen that the time periods which disarmament can safeguard for peace vary within certain limits with the severity of the measures imposed, but we know from past experience that if only six months, or even three months, of breathing-space had been ensured, great calamities would have been averted, and I think there is no doubt whatsoever that properly conceived measures of technical disarmament would safeguard much longer periods and convert a possible explosion into a feebly burning flame. All we need say at this point is that the main objective of disarmament is to safeguard the maximum possible period for the mechanism of peace from the time when war appears imminent.

Recent examples will clearly focus this point. We have evolved the idea of an inert period, beginning at the moment when a great nation decides to make war, and during which, owing to the state of armament, both as to quantity and organisation, no first-class decisive campaign can be undertaken. What was this period in the case of the four chief fighting nations in 1914 ? In the case of Germany and France there was no such period for all practical purposes. Enormous armies, highly and plentifully equipped, took the field, and engaged in some of the world's greatest battles within a few days. Of course there were shades of difference. Germany had great superiority in machine-guns and heavy artillery, and France was probably in a superior position as regards light artillery, but from the point of view of disarmament the main requirement, the enforced breathing-space, was non-existent. In the case of Great Britain, the period was very short in the case of sea warfare, and to all intents and purposes we could have brought our maximum force to bear upon the

situation in a few days or weeks. But, important as naval matters may be in many ways, they are not so critical to disarmament as land armament, for the simple reason that in a great war they cannot enforce a rapid decision, and, indeed, can only be decisive through their own powers in very long periods of time by indirect methods. We must therefore turn to Britain's land forces, where we find a very different story. Our inert period was certainly longer than twelve months, and would probably have been between eighteen months and two years. The greatest effort of mobilisation of men and armament that the world has ever seen, with the possible exception of America, left us quite unable to enforce a land decision in a great European war, certainly for eighteen months, and probably for the whole period of the war. As we show later, even by the time of the Somme battle, two years after the start, our great munitions effort had not yet begun to make its real contribution. The American position approximated even more closely to disarmament in the sense of our definition. Very few people realise that in spite of the extraordinary American accomplishment in the mobilisation of men and material, her inert period in armament was such that the war was over before American munitions began to reach France in appreciable quantities. It is safe to say that had all the nations been in the same armament position as the U.S.A., or even as Great Britain in 1914, there would have been no World War, or in any case we should have had a period of twelve months or more during which the forces of peaceful settlement could have been active.

Now if we visualise this disarmament objective, the so-called inert period, from the point of view of ensuring it in the future rather than its more or less accidental occurrence in the past, we are at once led to consider the factors which could be employed to create and safeguard it, and we enter the main field of technical disarmament. Nations commence hostilities with their existing armament equipment. Is this all that needs reduction and control? Various official schemes have been put forward on this assumption, and they have absorbed many months of the world's official periods of deliberation. This point can only be settled by exposing a wide range of armament facts. If the nations were to standardise on small quantities of existing armament, but vast resources were available for manufacture and supply, we require to know how long these would take to equip a great army. Without this information we are quite unable to judge whether the condition would be one of disarmament or not. Further, using

armament in its widest sense to include combatants, we are faced with the question of reserves and of the time periods required to train and organise civilians. These points must be examined, and not allowed to rest on opinion, for until that is done it would be folly to base world disarmament on the reorganisation and reduction of existing weapons and combatants alone.

Assume for the moment that after examining the facts we reach the conclusion that the disarmament scheme must deal with production as well as with existing capacity. Can we then say that these two fields cover the requirements of the problem, and that a complete solution can be found within those limits? This would clearly be the case if there were no other armament activities by means of which hostilities could be started and carried on, or in any case no other forms capable of making such a substantial contribution as to disturb the peace equilibrium which we might establish; but the position is that there is another vast field of armament activity, the whole question of the development of new weapons or the new agencies of war, a process which is going on all the time, and actively. Could this movement damage or destroy an otherwise rational scheme of disarmament which might be established? This is again a matter of fact and not of vague opinion. The processes of arms evolution can be examined; they follow certain natural courses. Their present direction is known, and, although their time periods of development cannot be fixed with mathematical accuracy, or even with the same exact knowledge as we possess regarding the production of normal armament, yet sound conclusions can be reached in terms of evidence, and we need never flounder in the manner which has characterised the rare official contemplation of this subject. This is a rough survey of the field which technical disarmament must cover—existing armament in quantity and production and the new agencies of war.

We can now consider certain questions of detail. It is perfectly clear that to be faithful to the scientific method we must, for any specific branch of disarmament, establish certain facts, endeavouring to make them representative of the situation. On these we can base our conclusions. The first step is to decide what type of fact is significant. This is attempted in a discussion on the nature of modern armament in the chapter on "Armament Potential." This leads to the broad classification of the subject under normal armament and the new agencies of war. In each case we try to establish the development and production characteristics of the

main forms of armament, in order to allow us to conclude their bearing on disarmament. There is, of course, no point in describing the technical details of the relevant manufacturing processes, for only certain features require emphasis, chosen because of their relation to our problem. If in some places I have digressed to a small extent into such descriptions, such as, for example, the story of Krupp, the history of the machine-gun, or the development of Lewisite, or have wandered into remote corners of Allied Countries, exposing interesting fragments of armament development from personal experience, it is with the definite purpose of inviting the reader to realise that this is a living subject, that the problem is pressing and continuing, and to leave him with a picture of the modern armament field in order to intensify if possible his appreciation of the important, but more theoretical, material which emerges from our discussion.

CHAPTER III

ARMAMENT POTENTIAL

War Potential : Armament Potential : The Conversion Lag : Sources of Information : Conclusion

Disarmament is a problem which has been created by armament; it is, in fact, the whole question of armament with a different objective: reduction instead of development, peace instead of war; and its solution must be found in a series of measures impinging on armament, leading to its reorganisation and governed by its facts. It would be an impossible task to conduct an investigation of this sort and within the limits of this book by a complete exposure of armament as an applied science. Indeed, it would not be helpful, perhaps harmful, to do so, but we must get an adequate and general view to enable us to pick out the facts which matter, and this can be done by developing the idea of armament potential. Many readers may be familiar with the term "war potential," and may wonder whether we are not confusing the two. On the contrary, it is desirable to draw a sharp distinction.

WAR POTENTIAL

This term has arisen at Geneva and in other centres of disarmament discussion on various occasions, without very clear definition. The idea of "potential" has been widely employed in the sciences, usually suggesting stored sources of energy or power, held in check but able to be released, and thereby converted into active forms of energy able to do work. The application of the term to war is apt, and arises somewhat as follows.

In the earliest days, the whole tribe or community was, in effect, on a potential fighting basis. Later, when war became the sport of kings, the profession of hired mercenaries and the stage and workshop of chivalry, this was no longer true. The elements of national activity quickly realisable for war were limited to armies, navies, arsenals, and those organisations which directly served them. There were, of course, exceptions, but as primitive forms of manufacture developed, and began to feed armament, there was a

sharp line between the war and peace activities of nations. Napoleon, however, was largely responsible for the new fashion when he placed the whole nation on a war basis. Since then the scientific and technical developments of peace have given birth to industries which have cradled and fostered armament to such an extent that it has become increasingly difficult to distinguish between the assets of a nation for war and peace. The phenomenal developments of the Great War have so increased this difficulty that it becomes necessary to regard a nation as living in a state of inherent preparedness for war, whatever its intentions or moral outlook. This would be true for any modern industrial country, even if the reins of power were in the hands of pledged pacifists and conscientious objectors. The linkages between pharmaceutical and dyestuffs intermediate products and poison-gas, deep-rooted in pure science, ignore the existing political regime. Such features are inherent in a first-class modern community, whatever the national outlook on peace may be. This merging of the peace activities of a nation into the means of making war at all points in science and industry has become such a marked phenomenon as to demand a name, and it has been called "war potential."

The conception is not new. Marshal Foch, emphasising the teaching of Von der Goltz, wrote, ". . . mobilisation nowadays takes up all the intellectual and material resources of the country in order to secure a successful issue." The late Lord Moulton has expressed the same idea: "Man mastered transport, aviation, telegraphy, and the like in order to add to the conveniences of peace. It was a result, though not a motive, that he thereby revolutionised war."

The use of the idea of war potential in disarmament has been too vague and diffuse to be of real value up to the present. The elements of the peace potential of a nation which can be diverted to support war comprise all kinds of factors of the greatest importance which have no bearing on technical disarmament, and only confuse the issue. Moral and mental forces are brought in, the education of the people on militarist lines; there is hardly an industry or a branch of science which does not in some way contribute to war potential, although the element in question may be so remote from armament, and so removed by a large number of long-period links in the chain of development, as to have no bearing on technical disarmament. Great industrial nations might be practically devoid of the direct means of making war, might

be removed from it by several years, and yet possess vast war potential. The loose employment of the idea has retarded disarmament to a certain extent. There is the general recognition that disarmament must be a process of reduction, eliminating the gross disparity in armament amongst the different nations. But as the idea of armament has become deeper and broader the tendency has been to think in terms of disparity in war potential. Certain less industrial countries represent a state of very low war potential. Now it is clear that we cannot as a disarmament measure change the industrial nature of a nation, and thus increase its war potential by that means. The suggestion has therefore arisen that in cases where war potential is very low such nations should be compensated by being given extra capacity of actual armament or weapons which could be employed quickly by the striking force. Carried to excess, the result would be to defeat the main technical objective of disarmament—the prevention of sudden outbreak through the existence of disparity in those forms of armament which could quickly be employed for war.

But the idea of war potential becomes extremely valuable in building up the framework of rational disarmament when we examine it closely in terms of facts, and thus narrow down the field. In a nation at peace one can recognise hundreds of different factors the total of which represents its war potential, but in the future, a world framing disarmament schemes or a nation co-operating in them must go further, and analyse or dissect war potential, for no disarmament scheme under present conditions can hope to lay a controlling hand upon every element of national preparedness for war. Whilst we maintain the present form of national and economic world structure, the most that can be done is wisely to choose certain key elements of war potential the control of which will afford a reasonable check on the more numerous remainder. Random choice is futile, and control, to be of any use, must be based on a clear view of the structure of war potential.

If the main objective of disarmament were to impose years of essential preparation upon any nation thinking of war, disregarding interference with its economic well-being, it would then be necessary to deal drastically with every possible element of war potential. But this would be quite impracticable, for it would mean rooting out important sections of vital peacetime industry, narrowing the field of important peaceful research, and changing the face of modern civilisation. To make real use of this potential idea we must return to our much narrower but very important

and adequate disarmament objective—the prevention of the rapid outbreak of large-scale hostilities. The logical need is to reduce existing armament to the permitted limits of defensive or police requirements, having in view that they must be sufficiently low to safeguard an adequate period for the methods of peaceful settlement. We must then look back into war potential and isolate for control those elements which might disturb the disarmament condition so created. In other words, the standard is to deal with the minimum number of elements of war potential and not the maximum.

Perhaps an example will best show how the scope can be limited. We find a great cellulose pulp industry supplying paper for the press ; heavy chemicals, acids, and alkalis feeding soap and fertilisers ; organic solvents supplying perfumes and engine fuel ; all contributing to the manufacture of modern explosives. These primary industries are elements of war potential. Does disarmament demand, therefore, that they should be controlled ? If it were found that they could move from their peacetime activities to the bulk production of complete high-explosive shell ready for use in a few days, the matter would have to be considered. It would enormously complicate the whole question of disarmament, and probably make it impossible. But if the real position is that in the absence of shell-making and shell-filling capacity, and in the presence of a scheme limiting artillery, we have an enforced period of essential development of several years, then the situation changes entirely, and it becomes quite unnecessary to cope with these remote elements of war potential, certainly until the subsequent phases of actual armament development have been explored.

We could multiply examples, but the final conclusion is that we are not concerned with the whole wide field of war potential as regards practical scientific disarmament. The method of approach is to concentrate on armament and the near factors which foster and revive it.

ARMAMENT POTENTIAL

In other words, it is armament potential which should claim our attention in the first place. We start by considering the striking forces for war instead of the whole range of factors which contribute to national power, the apex of the pyramid instead of

its broad base, which is a much simpler, shorter, and more practicable task. Let us pursue this analogy for a moment. We have at the apex a point which represents the military striking force, the armament which could be released almost instantaneously for war. At the base we have a whole range of peacetime activities, largely industrial, which feed the striking force through a series of processes which occupy varying and usually long periods of time. We have to determine some particular plane or level, a section cutting across the pyramid, above which it is absolutely essential that armament be subjected to measures of disarmament, and below which the time periods of availability of the items of armament potential are such that they do not materially affect our problem. It is a question of the maximum reorganisation of regions near the apex and the minimum interference with those near the base. Following each stream of armament activity from the apex to the base, we shall find that in some cases disarmament requirements cease very near to the apex—say in the control of a weapon and official factories to produce it—whereas in others technical considerations will impose disarmament measures deep down towards the base of the pyramid, far into the peacetime activities of a nation, as in the case of scientific research in connection with certain new types of weapons.

It becomes increasingly clear that the crux of the matter is time. We must study the different forms and fields of armament as processes of development. For the purposes of disarmament they must be classed, set aside or dealt with on the basis of the time periods during which they reach maturity for war. The problem is rather similar to that of an industrial expert making a movement study of the different processes in a great works. He is concerned with every step from the raw materials to the finished article, to ensure the maximum efficiency and speed of production, not only in each department, but through their interlocking. It is essentially a problem of development or process periods, but the objective is the maximum and best performance of the organisation as a whole. Disarmament has to consider a great field of industries and allied activities from a similar technical point of view, but with a different objective, which is to isolate certain links in the whole chain of events possessing the necessary characteristics themselves, or through their interlocking with others as to limit and check performance, instead of to improve it.

THE CONVERSION LAG

It will be useful to have a name for this time period which applies to each element of armament potential, and I have coined the term " conversion lag." It is not an exact period in terms of the nearest day, but, on the other hand, it enables some sort of measure and fair comparison to be made in a field which is otherwise chaotic. It would be well to consider an example. We can draw upon armament experience in the war and visualise a soap works in the heart of France peacefully making soap. One of its technical directors knew that his works was an element of war potential in the sense that it might be diverted to the manufacture of mustard gas. He did not think in terms of armament potential, but the effect was the same. On a given date, at a meeting of one of the French armament committees, this element of armament potential was released, and, by a series of processes of chemical research, reconstruction of plant, and reorganisation of labour over a period of many months, there emerged bulk supplies of mustard gas. The period involved was the conversion lag, but not the whole of it, for the bulk supplies so obtained had at that point no effect whatsoever upon the fate of the war. The liquid mustard gas was conveyed in special containers to a gas-filling station about a hundred miles away. Here a further element of conversion lag came into operation, not only because filling was a tricky problem, but because the gas requires special shell, and there was a glass works near Paris making frantic efforts to meet the need for special shell linings. Similar efforts were being made in other parts of France in the design and manufacture of the special boosters and fuses required. The net result in this case was a composite conversion lag of between twelve and eighteen months, the interval which was absorbed on essential steps in the process before the efforts at the soap works had any effect whatsoever upon the activities of Allied artillery on the front.

Many other examples will arise in the pages which follow. They will show that conversion lag varies in each case according to the special circumstances, yet they will establish what all our general industrial experience compels us to admit—that conversion lag reveals broad, common characteristics for the different classes of armament potential.

These considerations begin to give disarmament the appearance of an interesting and promising academic problem ; they appear to introduce order into the subject ; but their value and application

is far more practical. We can focus this point and realise it sharply by taking one or two special disarmament questions which have been debated for ten years or more. They are dealt with in detail and in their proper place later on, but let us examine them briefly.

On various occasions, usually coinciding with official conferences, disarmament has looked at chemical warfare. It has asked whether research could be controlled, and thereby new weapons submerged ; or whether chemical industry was a danger, and needed reorganisation ; or whether large-scale military field tests should be limited. These and other questions have come up for solution in no apparent order or relationship, and the practical results, as we know, have been negligible. It is difficult to see how, in the absence of some guiding principle, any real results could have been expected, how such questions could be answered, or how their bearing on disarmament could be determined. But bring in the idea of the time factor, the conversion lag, the interval between the peacetime element of armament potential and its war availability, and we at once begin to introduce order into the problem. We begin to class all the factors which contribute to chemical warfare in this way, and we build up the conception of a composite growth, a number of processes which interlock and possess their own conversion and technical characteristics.

Thus it emerges, so far as supplies of the chemical are concerned, that the various forms of scientific and military research have their own long conversion lag before manufacture can be contemplated. At that point we visualise supplies from new factories or from the existing chemical industry. In the former case we see the evidence of conversion lag is overwhelming, and even in the latter it is realised that organic and other chemical intermediate products from existing factories are useless until we have plant to convert them into poison-gas. The obvious point then arises that great stocks of war chemical have no meaning for war unless the appropriate containers or chemical weapons have been designed, and it follows that the existence of suitable weapons is useless unless we have vast factories ready to produce them. Then, even if we have passed through the periods involved in producing and accumulating stocks of chemical and container or weapon, we are still removed from war by a long known interval unless we have vast filling stations. And, to conclude, even though we have not yet covered every item of delay, all this is useless unless we have

developed through a parallel series of steps of manufacture and investigation such adequate protective devices as would allow these chemical weapons to be employed by our own troops.

Unless we regard it in this way as a series of processes with their own known characteristics, the whole subject is a morass in which a sound judgment is almost impossible. But with the time standard before us we find masses of known facts sorting themselves out, giving us a real idea of what disarmament measures are necessary, how much of the whole field needs to be brought within their scope. More important still, we can then begin to appreciate the interlocking effect of all these aspects of chemical warfare and the consequent reinforcement of all the possible disarmament measures in their combined effect.

There is another very interesting case from the recent practical politics of peace. On two or three important official occasions the use of biochemical and bacteriological methods for war has been considered. It is a gruesome subject, but a real danger. So far as one can ascertain, the disarmament efforts of the official world on this matter have been limited to the following. Reports have been called for from bacteriologists of world-wide reputation, and they have established that this method of warfare has great and horrible practical possibilities. Constructive disarmament measures have again been diverted and submerged by the general but fundamentally wrong assumption that because it would be difficult to prevent the discovery of new potent bacteriological forms, therefore nothing can be done beyond warning the world of the danger, and, worse still, holding out the ever-present threat of reprisals. It is a little unfair to sum the matter up so briefly, but this is actually and substantially the total of official efforts to safeguard us in this matter up to the present. What is the real position ?

A discovery is not, and never has been, a weapon, and by itself has never had any incidence on war. To-day the world possesses very few bacteria or similar organisms which could be safely employed in war. To the extent of present knowledge, which may not be complete, the normal objectives of bacteriological science have not diverted in the direction of war types. Possibly a few years of concentrated work for the purpose would produce such types. Here is the first element of conversion lag, which offers some hope of disarmament measures. Now, although we cannot be certain that no nation has begun to threaten the world by developing these types, we have much more certainty that no

real success has yet been achieved in developing the bacteriological weapon as distinct from the germ. Unlike the case of chemical warfare, no technique was developed during the war in this matter, no official research stations and testing-grounds were established, and anyone entering this military field after the war would have been compelled to start *de novo*. It is practically certain that here there is a conversion period of a number of years to be traversed before the threat becomes real, and on all known reasoned grounds it is extremely unlikely that the work could be done without definite and highly organised official assistance. This further element of conversion lag offers still more promising ground for disarmament measures.

Going a step farther, we find still greater obstacles, and more hope for the organisation of peace. The threat cannot mature without large-scale production of all the factors concerned as regards the germ, its media, its containers, and the actual weapon —presumably a shell or bomb. In this case armament potential is negligible, probably non-existent. There is no industry which would feed this field of armament as, say, the normal chemical industry feeds chemical warfare. There is no case of very large-scale production of such organisms as commercial commodities, and the large-scale handling of disease organisms is unknown. At least we hope so.

So we have a combined factor of conversion lag in this form of armament which would be extremely long if the matter were dealt with promptly, and, far from the despairing cry that nothing could be done because a discovery might occur at any moment, the disarmament aspect contains all kinds of solid and reassuring possibilities.

These are only two examples ; others will be found later ; but surely they indicate that there is no need, and this is no time, to stand appalled and helpless before these awful possibilities.

The moment we consider disarmament from the scientific point of view we stand face to face with armament and with a great number of elements of armament potential, which at first sight it would appear might have to be considered in the disarmament scheme. A reasoned choice must be made or the proposition is hopeless, and we have outlined very roughly the lines on which this can be done, but so far our thoughts have been in terms of armament as materials, and we seem to have ignored combatants and man-power. The general principles of scientific disarmament which apply to materials will also be found valid for men ;

armaments will not differ in theory from combatants, cannon from cannon fodder. But these two types always seem to be regarded as essentially different, so that I shall deal separately with the question of combatants and armament personnel.

Every man, and, in fact, every woman in a modern industrial country, must be regarded as armament potential. We could list the different kinds of armament activities towards which the people of this country contributed during the war, and for which they are to-day potential assets, and there would be tens of thousands of items. Scientific disarmament again requires a decision as to which of these must be brought within its scope. In the absence of any guiding principle the problem is incredibly complex, almost insoluble, but as soon as we bring in the idea of the time factor, the conversion lag, themselves emerging from the definition and the logical needs of disarmament, the problem clarifies. Here, for example, is a typewriter factory which was once converted to make machine-gun parts. Must we cripple this factory and those like it in times of peace by limiting their personnel? We know that they can make an eventual contribution to a future war, but when and how soon? We must know if the conversion lag is, say, a matter of twelve months, or overnight; if some other essential part of the machine-gun made elsewhere involves a parallel or extra period of delay, or whether the assembly of all the parts into finished guns from a complex industry supplying hundreds of different parts superimposes a further long conversion, which in fact it does. It is not enough to say, as in the past, that here is an element of peacetime industrial personnel which can make contribution to war, but we must probe much more deeply with a guiding principle.

Turning to actual combatants, fighting men, there is no other way to ascertain their bearing upon the scientific requirements of disarmament. The matter of existing organised combatants, the standing armies, the actual striking force, is relatively simple—a problem of military arithmetic, staff judgment, compromise, and international agreement; but here again, in the lower strata of the pyramid of combatant potential, we have a number of perplexing types whose disarmament aspect clarifies when we think in terms of development periods, and apply them to those critical questions of reserves, specialist soldiers, and the semi- and pseudo-military organisations.

We must admit that there is a special disarmament problem associated with combatants which hardly arises with regard to

armament as materials. Existing armament, such as heavy guns possessed by any nation under a disarmament scheme, represents a quantity. If the scheme is properly conceived, this quantity will be limited and known, and not increased by evasions, such as the constant renewal and setting aside of part of the original capacity into a hidden stock, for, indeed, the control of the latter must form part of the scheme.

There is a difference in the case of combatants. Men officially introduced into the agreed standard army cannot remain there indefinitely. There must be periods of service, and we have a process of rotation, starting with civilians becoming absorbed into the military machine and then being rejected by it and thrown back into the peacetime activities of a nation, where for a period at least they will represent a rapidly available asset for war. Here we have a case, and the only outstanding one, in which, even under a disarmament scheme, some of the permitted capacity actually creates armament potential, and cannot help doing so. This idea is at the root of the disarmament problem of reserves. Its importance will be seen when we come to consider the relative bearing of volunteer armies with long periods of service as compared with short-time conscript armies. Other vexed problems, which up to the present have been dealt with almost entirely in an atmosphere of tradition and emotion, become simpler and clearer by these methods. Thus the position of officers' training corps in England, and their equivalent organisations on the Continent, reveal their true disarmament bearing as we begin to examine their nature and class them in terms of combatant conversion lag.

Finally there is an all-important problem which we cannot avoid without seriously weakening any conclusions at which we might arrive. It is the question of aircraft. This is so important that it has often been said that unless something can be done about it in a disarmament scheme the rest is futile. It is easy to make statements of this sort, and they are not necessarily correct, whatever the authority behind them and however often they may be repeated. But the fact remains that there is a great deal of truth in the claim. If a disarmament scheme were adopted which did not in any way impinge upon the military use of aircraft, the position would be open to the gravest criticism, and there would be a great and growing sense of insecurity. This problem is in no way removed in principle from the others to which we have referred, and is capable of exactly the same treatment. In this case, official

discussion has not ignored the idea of conversion lag, and has repeatedly emphasised the extraordinary speed of such conversion, and the impossibility of any rational safeguards. No examination such as the one upon which we are embarked could accept such a claim without close examination. It is true that aircraft represent a case of rapid conversion. But we have to ask what this means in terms of facts, and as soon as we look into them we find that the case is not by any means hopeless. Except in the case of certain military types which can be dealt with under a disarmament scheme, other forms of aircraft are not necessarily weapons. Their conversion lag is governed by that of the real weapons which they employ, and, more than this, they cannot employ such weapons until they are suitably modified for the purpose. Such points must be examined in detail, together with the question of aircraft combatants. A judgment can only be made when we have considered each of the processes which could lead to the bulk use of aircraft in war, the disarmament measures which could be applied to each, and, in particular, the much increased safeguard which is always obtained by their interlocking.

SOURCES OF INFORMATION

The following chapters attempt to apply such ideas in detail over a representative field of armament. So far we have established certain very broad principles, and given one or two sketchy illustrations of their method of application. The first need is to expose an adequate range of facts, and we must confess that there are certain difficulties. It is not possible to state in a hard and fast manner that such and such a form of armament requires a fixed stated period of development. Such information has not even been collected and classified for peaceful industrial production, and it is very doubtful whether the problem has ever been viewed centrally in this way. We have to examine the records of armament production, particularly those which correspond with periods of feverish development, which represent the maximum threat in a state of disarmament. Those records are scattered, and in any case they have never been put together to throw light on our particular point of view. Fortunately, in a large number of cases we can get real evidence, and in others there is sufficient general information about the operations involved to reach a conclusion when we supplement it with our general technical and

industrial knowledge. The problem is very new, and we could only gradually build up our structure of evidence and leave it to the reader to judge whether it is adequate.

Where can we examine growth of armament, its birth, development, and production, expansion from very low to high armament equipment ? Events in Germany between 1870 and 1914 would be intensely interesting, for in one generation Germany improved the type and quantity of her armament beyond all knowledge, overcoming countless technical difficulties. But time was in her favour. Suppose, however, that during that space of forty-four years she had been content to reach the same stage of excellence in type and design of armament without production capacity. Could she then have made war in 1914? The decision would have depended entirely on the time factor, the period involved in developing and maintaining the vast equipment with which she opened hostilities. Had the conversion lag been a few days, or even weeks, she might still have surprised the world, but had it been a matter of months or years there would have been no surprise, vast counter-preparations, and probably no war.

The German explosives situation provides an astonishing illustration. Nitrogen is the basic element in modern explosives, whose supply depends absolutely upon the availability of nitrogenous raw materials. It is hopeless to embark upon a great war without the certainty of such supplies. In 1914 the world's chief store was Chilean nitrate, and quite early it was clear that German supplies would be vastly reduced, if not cut off entirely. We know, of course, that she had huge stocks of finished shell and other ammunition, and behind them, probably, still greater stocks of raw materials. But plans were based on a relatively quick decision, and many of those who knew the facts took the view that absence of nitrogen would finish the war more quickly than any efforts of the Allied armies, if no other solution were found.

This is a case in which insufficient attention to an important element of armament potential threatened the German nation, but, whether by hazard or design, some attention had been given to the point. The great reservoir of nitrogen is the atmosphere, which is international, and the classical researches of German, French, and British scientists, notably Professor Haber of Berlin, had provided the scientific knowledge whereby it was possible to convert atmospheric nitrogen into fertilisers and explosives. Germany, with characteristic enterprise, had begun the industrial application of this process just before the war in her great chemical

factories on the Rhine ; it was one of the classic achievements of chemical industry, and was beginning to prove a feasible method for bulk production in the early months of the war. Thus, as the threat of nitrogen shortage increased, so the availability of explosives was restored by the Haber process, and this later proved the mainstay of the German explosives campaign.

Some years later a similar position arose through lack of supplies of raw rubber, which threatened the transport and gas-mask supplies of the German army. In this case, although the chemical industry produced a form of synthetic rubber, neither the quantities nor the properties were adequate to meet the situation in time. The research conversion lag was still in front instead of behind them. Thus, although Germany attended to armament potential in an extraordinarily efficient way, her own difficulties only serve to focus the critical importance of this matter for war and for disarmament.

What is the shortest space of time into which the development of a nation's armament can be compressed ? How do the different forms of armament contribute to the delay ? So great is the importance of such questions for our purposes that it is indeed fortunate that a very complete answer is provided by the U.S.A. In 1914, when war broke out, and even in 1917, when she entered it, this great country possessed an equipment of armament which, compared with that of Germany, was much less advanced in type and design, and hopelessly behind in manufacturing capacity. Yet conditions were probably more favourable in the U.S.A. for the rapid elimination of these differences than in any other country. Possessing unlimited wealth and resources, a wonderful corps of engineers, mechanics, and scientists to exploit them through her fine industrial organisation, having all the will and incentive to direct these vast facilities to armament, and favoured by her years of warning and remoteness from hostilities, it is doubtful whether any country could have moved faster, or as fast. Thus the armament conversion lag of the U.S.A. becomes evidence of the first importance in the case for or against the value of disarmament. We shall examine this, and it will also be valuable to place beside it information available from other countries.

CONCLUSION

The essential characteristics and facts of armament necessary for our subject will now be examined. They fall, according to their

technical characteristics and their bearing on disarmament, into two classes—normal armament and the new agencies of war—and will be considered in that order. We shall then be able to proceed to develop and apply the principles of disarmament and deal separately with the problems of combatants and aircraft.

When this point has been reached in the chapters which follow, the reader will have before him a number of guiding principles, a sort of structure of disarmament theory based on facts, which will enable him to judge the technical validity, and therefore to a large extent the eventual practical value, of any disarmament proposals which may come forward. Finally, I thought it of interest and value to give a very short description of technical disarmament proposals which have already emerged, some of which will probably be ventilated and pursued officially in the near future, and I have attempted to examine how far they are consistent with the ideas and principles which we have evolved.

CHAPTER IV

THE EXPANSION OF ARMAMENT: NORMAL TYPES

The Relevant Evidence : Comments on Total Expansion : Gun Production : The Recuperator : Krupp : Shell : The Machine-Gun : The Rifle : Small Arms Ammunition : Conclusion

THE RELEVANT EVIDENCE

We have to seek facts which will give us a true picture of two broad aspects of armament. The more immediate problem—the one with which we are concerned in this chapter—relates to existing weapons. We imagine the situation in which the world has agreed to disarm, and has reached a state of disarmament which gives to each nation an agreed, known, limited quantity of armament. This means a fixed quantity of existing weapons and of capacity to produce them. An important question would then arise : in what period of time could any nation move from its disarmed position to one of vast uncontrolled armament, able to threaten the stability of peace ? In other words, is the disarmed condition real and effective ? In order to test the situation, or intelligently to bring it about, we need to obtain the best possible idea of the time periods of armament development, and we have to examine what I have called above " the expansion of armament."

The second problem which disarmament must probe, and for which we need information, is not the expansion of known types, but the development of new ones. It is an entirely different problem, although in places it involves the same type of knowledge and fact. It is, in effect, the development of the new agencies of war, a process which, if it is not in some way controlled, will continue its present growth, irrespective of normal disarmament measures, and will at a given point defeat them. This matter is dealt with separately later, and we can now return to the simpler question of normal armament expansion.

Armament has been concealed from the general view by a fog which, apart from certain official activities, has been allowed to arise far more through public apathy than the intention of those

interested in the development and manufacture of weapons. The searchlight of public interest and opinion has been turned on to the subject on very rare occasions, and then usually with a strongly biased motive and objective such as to pour abuse upon armament manufacturers. As soon as we pierce the barrier with a cold and purely technical beam we find ourselves in a wide industrial field, a hive of activity of manufacture, research, and design, concentrating on the production of a limited range of actual weapons and other forms of finished armament. Our first object is to consider the time periods of expansion, and the characteristics which control them, of the chief types and processes involved. We must also see how they interlock in the creation of a great industry, and how this final synthesis may influence the total period of expansion.

Consider one illustration. Disarmament is assisted, and the possibility of war made more remote, by limitation of artillery. The latter is helpless without adequate supplies of shell. These must therefore be considered by disarmament, which means that we must examine the conversion lag of shell production. No judgment can be made on shell alone, but, on the other hand, we cannot ignore this section of armament. We find the claim advanced in serious disarmament conferences that shell can be produced in a few weeks, meaning, presumably, that a nation with limited stocks and manufacturing capacity could begin large bulk supplies in a dangerously short time. Now, if this were so, it would be of the utmost importance for disarmament ; it would mean that shell production could not be regarded as making its contribution to the safety period. Therefore we must intelligently satisfy ourselves on this and similar claims. How can this be done ?

There is only one way which appeals to reason, which is to take actual known cases in which an industrial nation with great facilities, and under fierce stimulus, rose from feeble to vast shell production. We must find concrete cases in which the periods are known, and, although these are inadequately recorded, they do exist, and such evidence is produced in this chapter. If we find that there is no case for conversion in a few weeks, but many months are required, which is the true position, we not only realise the great danger for disarmament of a failure to explore the facts, and of resting on vague opinion, but we at once reach a constructive element of information which can be employed, with others, to visualise the whole field in a representative manner. Thus, moving from shell to heavy guns, machine-guns, and the

whole range of major weapons, we assemble the evidence which is relevant to the expansion of armament.

The reader may experience some impatience at the prospect of having to survey so much technical material, but he should remember that such an investigation has never yet been made, and he is breaking new ground, the exploration of which is absolutely vital to sane disarmament.

The final objective is to reach conclusions about the expansion of what is substantially one great industry. Very few have ever conceived the magnitude of the effort involved. The general, and indeed the official, opinion has centred round the idea of great armament industries springing up overnight, so much so that the phrase "overnight conversion" has almost become a technical term. This has arisen, of course, through unjustified generalisation from some exceptional case to the whole field of armament, but we must not be led astray by such short cuts to a technical judgment of vital importance.

There is no better approach than to consider the nature and magnitude of the American effort when that great country developed from what was in fact a disarmed nation at peace to one of the most powerfully armed in the whole world.

COMMENTS ON TOTAL EXPANSION

In 1914, the American Ordnance Department comprised a mere handful of men, less than one hundred officers in all, yet eleven thousand were eventually needed to cope with the needs of the army in 1918. Six Government arsenals and two private ordnance works completed their manufacturing capacity, yet in 1917, stimulated by Allied demands, about twenty firms were engaged, while by the Armistice some eight thousand were working on ordnance contracts. This terrific industrial expansion finds no parallel in peacetime industry, nothing approaching such development of producing capacity in two or three years. Its extraordinary velocity can easily be seen by visualising the speed of development of a great modern industry. Portland cement, now the backbone of modern building, has moved from the manufacture of relatively small tonnages of a new material up to vast modern production in a space of at least fifty years. In England the present production is about four and a half million tons per annum, absorbing, at the most, a manufacturing personnel of fifteen thousand people, working in about twenty factories.

British artificial silk has taken at least ten years of intensive development to reach the present position of a great national industry, with some half-dozen great works and a larger number of smaller ones, labour and staff totalling at the most twenty thousand.

These figures of great peace enterprises are to be compared with a war expansion in armament manufacture from about ten works to nearly ten thousand, involving about fifteen thousand specialists and several hundred thousand workers, consuming about four thousand million pounds in about two and a half years. The American munition authorities have made the interesting comparison that this industrial effort and expenditure could have built nearly forty Panama Canals, and a rough idea of what that project involved enables us to bring the magnitude of the American armament effort within the range of human conception. To bring the comparison nearer home, visualise the extraordinary chemical development in England during the last ten years. We now have a national capacity for organic chemicals, heavy chemicals, and special bulk chemicals such as ammonium sulphate, which includes the powerful dye industry, with several great modern works, and the enormous nitrogen industry on the Tees. At the most, a few hundred million pounds have been diverted for development and working capital. The American munition effort, taking into account its much greater expenditure and much shorter development period, assuming the necessary knowledge had been available, could have brought to the same pitch at least fifty such industries.

What kind of effort was required to bring about this phenomenal transformation of the American industrial machine? Works were converted and new ones built. What were the processes and periods involved in this conversion, and how quickly did the new plants come into operation? It must be remembered that this incredible development occurred by the year 1918, during the four years of war, but mainly during the last two years, when America participated. At the end of this period, American armament production and equipment was probably considerably greater than the total similar capacity of the Central Empires at the outbreak of war in 1914. It is a very striking and significant fact that this great country, the U.S.A., with enormous facilities and a terrific effort, took at least two years to place her armies in a position to fight an enemy whose armament-producing machine had developed to the 1914 pitch. Even then this American effort

of two years was not alone sufficient to counter the war machine of the Central Empires, for the collapse of the latter and the final result were reached, not in virtue of the American effort alone, but by an equally drastic industrial struggle in France and the British Empire over a period of four years, with the important underlying fact that in these countries, particularly France, and to a certain extent England, the initial equipment, the starting-off point in 1914, were considerably more advanced than in the U.S.A. Broadly speaking, before the armament development of the Allies acquired a sufficient impetus to overwhelm the enemy there was a production lag of about four years. From the point of view of armament this was amazingly short, but for disarmament it would have been critically long, and it is of the utmost interest to dissect this process of armament development and identify those features which were mainly responsible for the delay.

GUN PRODUCTION

Turn first to the production of guns. Between April 1917 and October 1918, a period of eighteen months, U.S.A. gun factories increased from four, of which only two had the necessary equipment to make complete guns, up to nineteen which were practically in full operation in October 1918. The most rapid element in this growth was probably the case of the American Brake Shoe & Foundry Company, which commenced the erection of a plant in July 1917 for the manufacture of 155-millimetre howitzers. Their first production was shipped eight months later, which does not mean that the factory was in full blast, but that it was in a position from which supplies could be made and increased in a manner characteristic of any new factory. It probably took many months before they reached a steady delivery of maximum output. To most of us, obsessed with the idea of overnight production of armament, this seems remarkably slow. What does it really mean as a measure of speed? The United States Director of Munitions had clear and authoritative views on this point, emphasising that it was doubtful if the annals of industry in any country could produce a feat to match this. He was right. In this case, had the plant, personnel, and experience already existed, from eight to twelve months would have been saved. Facts of this sort give a more accurate meaning to the transition from peace to war production, and help to define that time factor or

conversion lag whose consideration is critical in any reasoned disarmament scheme.

Gun-carriages seem less removed from peace manufacture than actual guns, and surely in such a case we could expect rapid conversion, yet what occurred in this case ? In November 1917 orders were placed with American companies for some two thousand five hundred carriages for howitzers. These firms had every assistance and no lack of money, but failed to produce carriages for test before eight months had elapsed, although they worked with great speed, and had noteworthy success in production. Case after case can be examined, and although there may be exceptions, and although it may be a little unjust to some firms, yet this generalisation is substantially true. The most rapid development of the least complicated elements of normal armament required a period of never less than six, and often more than twelve, months between the decision to produce and the commencement of production, with a further long interval for steady bulk supplies.

THE RECUPERATOR

A different story, however, has to be told of new features in normal armament, requiring new processes or exacting new standards. Of these, the recuperator affords an excellent example. Not generally known to the average reader, this device is of the utmost importance. When a gun fires a shell there is a tremendous recoil, and, if the shock were not absorbed, two things would happen. At each discharge the gun would leap back out of direction for the next shot, and the gun-mounting would have an exceedingly short life period. Arrangements are therefore made to absorb the shock of recoil, and the mechanism in the very successful French types is called the recuperator. The incredible task performed by the shock absorber or recuperator of the ten-inch gun is seen by a simple comparison. The huge stationary buffers at a great terminal station of London or New York can cope with the shock of a hundred-ton locomotive at a dead slow speed—something less than one mile per hour—but they offer no effective resistance should the engine fail to retard speed to these limits. A hundred-ton locomotive travelling at sixty miles per hour could break through the most substantial station buildings and wreak untold damage. Yet the recuperator performs a herculean task equal to stopping the engine travelling at this speed, in a few feet, in less than a second, and without harmful shock. Imagine your

four-seater touring car, weighing about one ton, travelling at five hundred miles per hour. If a suitable recuperator mechanism could be employed to stop it, then the car would be brought to a standstill and the shock absorbed in about a yard of space and less than a second of time! Without entering into a detailed technical description of the recuperator, it is sufficient to say that its manufacture involved the same degree of precision as a scientific instrument. The peacetime industry adapted to this kind of manufacture was naturally limited, and probably no heavy engineering product ever before turned out in American factories required in its finish the mathematical accuracy essential in a recuperator. Add to this the fact that they had never been built outside France, and we find an excellent example of the difficulties involved in the transformation of industrial facilities from peace to war. In fact, American official opinion was that the production of recuperators might be regarded as the crux of the whole American ordnance undertaking, and the index of success in the industrial struggle against Germany.

The 155-millimetre howitzer recuperator was the first to enter quantity production in September 1918, well over twelve months after the orders were placed. The rough forgings came into quantity production in the spring of 1918, yet the first finished recuperators were not through until October, only thirty were accepted before the end of the year, and quantity production did not start until January 1919, a lag of about eighteen months. The 240-millimetre howitzer recuperator involved still longer delays, and the 75-millimetre gun recuperator came last of all. Here, then, we have a great industrial country devoting every available facility and effort to the production of a part of a weapon for which definite plant, personnel, and experience did not exist. Hitherto the French had been the most successful, if not the only, manufacturers of these intricate shock absorbers, and, in spite of assistance in the shape of French engineers sent from the great artillery factories of France, America took more than a year to reach quantity production. For the 155-millimetre howitzer recuperator, a solid forging of two tons was reduced to a quarter of the weight by boring out cylinders, the surface of which must be bored, ground, and lapped to a degree of fineness and smoothness of surface representing a precision hitherto unknown in American heavy manufacture. Working at the utmost speed, at least three months must elapse before the recuperator rough forging appeared as a completed mechanism for inspection. Many unexpected

difficulties arose, and the first models were thrown back by the inspection departments, although the work was of a high order judged by ordinary engineering standards, which were not sufficiently exact for these delicately adjusted hydro-pneumatic devices.

We can bring the matter nearer home to the British reader. The general experience of a long time lag in the development of gun production in Europe and in England was the same as in the U.S.A. Technical processes, although they acquire national characteristics, have to conform to scientific standards which are universal, and disregard nationality. The production lag in gun and shell manufacture is illustrated very well from the history of the Cammel Laird factory at Nottingham. This great firm was asked in July 1915 to create and manage the National Ordnance Factory at Nottingham, and the work was started in August 1915, simply with the object of shell production. The factory cost about a million pounds, and its actual shops covered more than ten acres. In spite of very high standards of efficiency and the great effort made, shells were not produced before nine months had elapsed, in May 1916. It was not until September, after twelve months, that the full shell programme was reached of two thousand 9.2-inch and six thousand 6.6-inch shells per week. The lag of one year represented quick development for an enterprise and output of this magnitude, and the further history of this plant illustrates very well the nature and speed of manufacturing progress under the changing conditions of war programmes. First, the 6-inch shell design was changed from the mark 4 to the mark 3 bottled shell, which meant radical alterations and additions to plant. Then, after eight months of shell manufacture for Britain and Italy, instructions were received in March 1917 to proceed with gun repair, and in April 1917 orders came for the new 18-pounder guns at about twenty per week. There was a fresh instruction in June 1917 to make the mark 19 6-inch gun. Some three hundred new machines were required for this gun manufacture, and the first 6-inch gun was finished and dispatched in September 1918, some fifteen months after the first instruction. At one and the same time, in this great factory reorganisation was going on from shell to gun manufacture, deeper foundations were being made for the gun machines, alterations and reductions were occurring in shell-making and gun repair work, gun jackets were being made for Vickers, tubes machined, breech rings and breech bushes completed and fitted. The cost figures give a good idea of the waste

of war. At this factory production was very efficient and cost low, yet 9.2-inch shell cost nearly eight pounds each and the 6-inch shell nearly three pounds. In other words, about two million pounds' worth per annum of metal in shell was leaving this factory to be blown to the four winds of heaven, with no practical utility nor recovery value apart from the war objective.

A description of some of the operations given in the *Sheffield Daily Telegraph* enables us to appreciate the detailed reasons for these time lags in armament development. We quote from the notes which were entitled "From Shell to Gun." "The particular gun made there now consists of two steel tubes, miles of ribbon wire, and a jacket. The tubes are known as the outer 'A' and the inner 'A' tubes in their rough forged state, which are placed in position at once on long bedded lathes. The exteriors are to be turned and the interiors taper bored, and as the tubes pass through the various processes they move onward to the top end of the bays. The inner 'A' tubes are unloaded . . . and passed onwards to lathes, the operation in this case being taper turning and boring. And here a notable exception to ordinary standardised work occurs, for the outer and inner tubes must be mated, made in definite pairs, the one for the other. Any inner tube will not fit into any outer tube, even though to the ordinary eye they are all of precisely the same dimensions. In boring the outer tube, minute irregularities of surface occur, and these have to be carefully ascertained by gauge tests and charted. The chart of an outer tube boring is then taken to a definite inner tube in the process of being tapered down, and the turner working to the chart reproduces on the surface of the tube every inequality or detail in the boring of the outer tube." "At the top end of the bays the two finished tubes meet and are built together. The outer tube is first lowered perpendicularly, breech-end upward, into a gun-pit about thirty-two feet deep, then the inner tube is brought by an overhead crane, placed in position, and driven home by a falling weight." Then follows the machining of the wire seat and the wiring on of twenty-four layers of wire, or about six and a half miles of fine steel.

Anyone with the slightest knowledge of technical processes or engineering industry will realise that the development and standardisation of the steps mentioned above more than account for the long time lag between instruction to produce and achieving the programmed output. May I digress and refer to the after-history of these wonderful destructive machines. Quite apart

from the question of capture, or destruction by counter-batteries, their life is very limited, so that with some of the heavier guns it was not possible to fire more than a hundred shells without returning the gun for minor and sometimes major repair. During the war the total life of an 18-pounder was reckoned at about ten thousand rounds, while a 9.2-inch gun was finished after one thousand. There is no parallel case in normal industry of a machine involving a similar effort of production and rendering relatively such small service. A big crane, locomotive, dynamo, or moving bridge carries on its useful work for many years, becoming obsolete usually, not because of failure, but due to technical progress, as in design, materials, or changed conditions of use. Any enterprise using such an article need only allocate a relatively low figure for depreciation. As against an annual figure of from two per cent. to five per cent. in normal industry, we would have to set for heavy guns for war percentages of nearer a hundred. As I have said before, the maximum latitude which nature and man's ingenuity will allow him for waste in the struggle of life is hopelessly surpassed in the standards which war imposes. It is a fever in the struggle against which humanity could only survive for short periods ; carried on indefinitely, it would inevitably destroy us.

KRUPP

The foundations of modern German artillery were laid by the House of Krupp, starting about thirty years before the Franco-Prussian War of 1870. Probably no firm in the history of the world has made such a big contribution to the development of one of the major sections of armament as Krupp of Essen. In their works, laboratories, drawing offices, and testing grounds the forerunners of the modern gun were born and fostered. Many years later they were produced with an intensity and on a scale which it would be difficult to parallel in any branch of industry, on any product. The speed of development could hardly have been improved upon or equalled by any other group, so the time periods of development are of the greatest interest, showing the characteristics of private or semi-official armament development in times of peace.

The beginnings of the House of Krupp provide one of the purest examples of industrial romance. Napoleon's famous embargo on English goods created a shortage of crucible steel and allied products in European countries. This was felt in the small but growing iron industry in the Rhine districts, in which Friedrich

Krupp was interested through the merchanting activities of his father. He had an inventor's mind and a desire to produce, and when the brothers Kechel appeared with a claim that they had a mysterious flux for the making of steel, for which Europe was panting, he took up their processes with more enthusiasm than caution. They started a small factory which absorbed Krupp's patrimony at a time when the young family could barely afford it, and struggled on until Krupp realised that the Kechel formulæ were ill-founded and could not succeed. The little crucible steel foundry and forge, served by the famous tilt hammer and the almost historical stream, were left while Krupp went back to his old means of livelihood. But the determination to manufacture the best English crucible steel was fixed, so when Nicolai, a genuine metallurgist with official backing and German patents, arrived at Essen about the time of Waterloo, Krupp welcomed him, and the factory started again under the new partnership. They made progress, and supplied cast steel bars and ingots for dies to neighbouring tool works and the Düsseldorf mint.

The partnership ended disastrously by a lawsuit in 1823, from which Krupp emerged impoverished but successful, to pursue his manufacture and inventions with a background of debt and family embarrassment. It is said that his annual turnover never exceeded four hundred pounds ; he rarely, and then barely, made a profit margin. The State, to whom he applied for assistance, refused it ; illness added to his troubles ; and, with his business practically at a standstill, he died in 1826, a courageous but disappointed man, deserving of all the admiration and praise which history has given him. Friedrich Krupp was probably the first metallurgist to produce what are now called special steel alloys, and, when he died, Alfred Krupp and his renowned mother shared the secret processes jointly in the inheritance. Under the new management, and with family assistance, the works made slow progress, and Alfred Krupp began to devote a great deal of time in exploring new industries which might provide outlets for his special steels. In this way he became well known in various Government establishments, and the State began to take the view that this new industry, kept alive only by the sacrifices and personal qualities of Friedrich Krupp, must be encouraged. It was about the year 1836 that Krupp and the War Department considered the question of rifle barrels, but no action was taken for another seven years. Krupp was pushing the use of crucible steel tools, and visited the national rifle factory near Mulheim, where frank technical discussions

went on regarding the possible trend of armament development, and he left them with two impressions indelibly fixed on his mind : crucible steel guns would provide a means of proving the great advantages and the properties of this material, and would be an important outlet for his manufactures. He offered to send the arms factory samples of such guns, but, in spite of preparing specimens himself, fully proving his claims, and volunteering demonstrations, he was not able to realise his hopes either in Prussia or in France and England, where he made several attempts to replace the iron and bronze guns by his superior steels. The technical armament world was not against him, and in some cases with him, but the departments would not move. The time was ripe for Krupp in France, which was reputed to have a wonderful military technique and equipment under the great Marshal Soult, and where revision and replacement of arms were under consideration, but, in spite of a most successful test by the French War Ministry, Krupp was only able to add to his reputation, and not substantially to his orders and works production. Cost was against him, largely due to the state of development of machines for boring and finishing. He then came forward with the suggestion of crucible steel inner gun tubes, which enabled cannon to be made of much lighter weight, with thinner walls, but the Ministries could not appreciate this, and simply wanted his tubes as a reinforcement for the existing iron guns, leading to a prohibitive cost, which Krupp saw was quite unnecessary. It is recorded that the specimen of the new tube which he sent to the Prussian Ministry remained in the artillery shops at Spandau for years without any action.

Finally, after a great deal of lobbying, a three-pounder gun was authorised and produced with a crucible steel inner tube, but although this proved exceedingly satisfactory under tests, the departments and Ministries could not be moved from the traditional cast-iron and bronze. The rifle factories, however, did take up his steels for barrels. The widespread storm of European unrest in 1828, although it delayed Krupp's gun development and shook his concerns, left him afloat when it passed, and from that time he never looked back. It is curious that Krupp, the pioneer of modern private manufacture of arms, should have received his first substantial order and commercial encouragement abroad, thereby signalling the international or, rather, non-national qualities, which became so characteristic of the arms commerce of later times. Said Pasha, Khedive of Egypt,

between 1856 and 1859 gave Krupp what was then a large order for thirty-six guns, which were made entirely of his steel. Prussian orders followed, and Krupp began to reap his reward in profitable gun-making, his technical reputation in steel being gradually left behind by the more popular one of the world's great armament manufacturer. It was about this time, 1850, that guns began to monopolise all Krupp's thoughts and activities. Their technical interest, commercial value, and the prestige which they brought through connections with Governments and Royalty had so increased that guns became an obsession. The forces which he had liberated and started on their way many years before had taken a direction and acquired a momentum which he no longer controlled, but which, through this powerful intellect and personality, controlled him. The famous Fritz, the 50-ton hammer, marked the beginning of this new epoch which was to have such sinister and far-reaching influence. Fritz was a supreme mark of Krupp foresight ; the decision and design were the fruits of nearly ten years' mental development. At first Krupp felt he must have this enormous hammer to cope with the great new engineering developments which were on the horizon. Great expansion in the size of ocean-going steamers and warships called for propeller shafts and other mechanical units for which his fault-free ingots of crucible steel would be the solution, but for this he must have a proper forge and other tool equipment, of which Fritz was the key, a hammer which would wake the Antipodes, and which in 1861 was already shaking the houses of Essen. But, during its evolution, gun orders, particularly from Prussia, had so increased that Krupp felt he had now got his teeth firmly fixed in the commerce of armament, and the hammer became for him a means of realising enormous guns which the artillery staffs had not yet visualised. Krupp had begun to make his great contribution towards armament development ; Fritz cemented the friendship and alliance between Krupp and Emperor and the State, and thenceforward they marched hand in hand.

In eight years, largely through gun orders, his works multiplied sixfold. The superiority of his guns was established in war in the Prussian campaign against Austria in 1866, which provided also powerful lessons as regards quantity and artillery concentration. Although the German army in 1870 was not entirely equipped with Krupp guns, yet these had a great further triumph in the Franco-Prussian War, leading to the re-armament of the German Field Artillery, the works again increasing some sixfold. In

January of 1874 Krupp received orders for some two thousand five hundred field guns, carriage parts, and accessories. The Emperor, insistent on a rapid re-armament, had fixed June 1875 as the maximum delay in completion. Although Krupp performed what was for those times a miracle of productive speed, he had the greatest difficulty in producing some two thousand guns in about twenty months. At that time, therefore, the lag in armament development was clearly such that a rational scheme of armament limitation and arbitration could have been made a thoroughly logical solution of the peace problem, particularly when we remember that nowhere else in the world could Krupp's feat have been emulated. Although the lapse of fifty years has made this problem more difficult, the contrast only brings out the need of operating soon some agreed scheme of armament limitation, without waiting for further changes to occur in the nature of armament and its production.

After 1870 the attitude of the German Government and its departments entirely changed. Krupp, during the preceding twenty or thirty years, had pursued an extraordinarily persistent campaign of diplomatic contact with high German officials, right up to the Emperor, who became his friend, and technical and educational contacts with the very strong and independent Ministries and War Departments. This had borne fruit, and Krupp no longer pleaded, but obtained privileges and favours previously unheard of. He was allowed, for example, to develop proving-grounds for his guns, where he not only made his own tests, but gave demonstrations to his influential customers.

It is claimed in Berdrow's memoirs of Krupp that the successful development of these testing-stations was the greatest achievement of his life, and the far-reaching consequences certainly justify this conclusion. Krupp had been steadily moulding the armament policy of Germany, and, indirectly, of other countries, but even after the war of 1870 his views were by no means generally accepted. His mind was playing upon the next war, and he was in a fever lest Germany should cast aside the armament advantages which, mainly through him, she had gained. He was far more concerned about the matter than the actual artillery specialists and staffs. The traditions and school of the bronze gun died hard, and the danger which he saw was the re-arming of the German artillery with a second-rate weapon, made from the metal recovered from the enormous captures of enemy guns. It was a threat to crucible steel which might lose, for his firm, the

well-deserved profits of twenty years of development, and for his country her leadership in armament. The Government had no testing-range worthy of the name, none capable of proving the superiority of Krupp's latest models. Only by demonstration could he convince the officials of the great muzzle velocities and ranges which he could offer, and compel them through crucible steel to adopt standards which without such proof would be denied and ridiculed. In order to get his country to use his guns, he had to persuade it to take a step through a private firm, his own, which was previously beyond the vision and ambitions of the Government and its military advisers. So we find Krupp, a determined man, pursuing his cause in Berlin in 1871 and 1872, swaying the Crown Prince, Bismarck, and the Emperor, and through them a reluctant army, to grant him the proving-ground at Dulmen, a poor substitute for the vast territory of Meppen which Krupp then had in view, but only acquired later. But Dulmen demonstrations and tests proved sufficient to overcome the residue of resistance and establish the Krupp gun. Meppen, with a maximum range of fifteen miles, acquired in 1877, at that time a unique and far-sighted development, remained one of the world's greatest proving-grounds until the Great War. On it Krupp could test his new monster guns, and on the first day of its use in October 1877 a 15-centimetre siege gun threw a shell a distance of more than 9,000 metres—the greatest range ever attained by a projectile up to that time.

Krupp's were now the only armament firm in the world capable of completely independent development of guns and other forms of armament. Other firms were in some cases dependent on others for raw materials, and never free as regards technical development. They were dependent on co-operation with military personnel as regards design, particularly at the stage of field tests, and exercised at the most a joint enterprise, but Krupp had seized the armament initiative with both hands. Hitherto the leader in development as regards raw materials, tools, machinery, and gun type, he now took over the one function which had always been, and in other countries still remains, the exclusive duty of the State, i.e. the testing and standardisation of performance of a new weapon on a large scale. When Krupp created Meppen, it meant that a private firm had usurped, through its energy, ability, and ambition, one of the most prized and secret functions of the State, with its consent. The possible consequences and importance of such an event spring to the eye, and will be examined in detail

later with regard to the operation of disarmament. At the functions which attended the first trials at Meppen, Krupp was hailed as the " Cannon King," but apparently no reference was made to cannon fodder. The long history of Meppen shows the extraordinarily critical part which it played in the development of the armament race so largely responsible for, or at least contributory to, the catastrophe of 1914, but I can only stop to give one example showing the unique freedom which Krupp enjoyed in the use of this vast artillery research laboratory.

Artillery staffs and the armament world were reacting to Krupp's ideas of monster guns with a range and projectile weight hitherto unheard of. He had not personally shown the same enthusiasm about the Meppen ground as some years before, when he acquired Dulmen. Financial responsibilities were weighing somewhat heavily upon him, but a good deal of his initiative had passed to his extraordinarily active and competent colleagues and staff, for the seed which he had first sown some thirty years before had become deeply rooted. They reminded Krupp that Armstrong's were at this time becoming a serious factor in armament competition ; therefore when foreign officers, Danish, Dutch, Norwegian, and Russian, made it known that as customers they were drawn to Krupp because of the great advantages provided by his proving-ground, which Armstrong's did not possess, Krupp saw the full force of Meppen as a very serious commercial factor. England and other countries were seeking heavier and heavier guns in the race between armour and projectile. Anticipating and in fact stimulating this movement, Krupp had sent to the exhibition at Philadelphia in 1875 a 14-inch monster. England was producing enormous muzzle-loading naval guns, weighing eighty tons, and Italy had a 17-inch gun, for which Armstrong's were constructing their Pozzuoli factory. In March 1878 reference was made in the British Parliament to Krupp guns which he took as adverse criticism, threatening his leadership. Krupp answered this challenge with spirit, and issued another, hoping to win England over once and for all to his crucible steel breech-loading heavy gun. He pressed that comparative tests should be made between his and Armstrong guns in England, and offered, if he proved successful, to pander to the British idea of independence in armament production by establishing a factory there, a step which he had persistently refused, even under strong pressure and inducement, in every other case. His challenge was not taken up ; for one reason, there was no satisfactory means of carrying out

such a test in England. Krupp offered the British the sole use of Meppen for a series of tests so long as they would bear the charges, but they refused, and out of this there emerged Krupp's international demonstration at Meppen in 1879, when the technical superiority of the Krupp monster gun seems to have been well established before the artillery specialists of all countries. He organised demonstrations for representatives from all parts of the globe, even including China, and he took them through his plants and showed them his wares. Turkey was at this time not invited, because he was in active negotiation with the Russians to supply them with armament in their war against that country, and the absence of France represented the one concession which Krupp made to his desire for national predominance. Meppen was freely used as a vast international showroom for the latest productions of the armament leader.

We cannot afford time to look into the other armament activities of Krupp, which have more bearing on our general problem than on the production of guns. We need only say that the same fierce energy was devoted to other kinds of armament, and the same methods of international appeal and demonstration were employed. A similar contest arose on armour plates between Krupp metal—K.C., or Krupp cemented plate—and the well-known Harveyed steel. Certain classes of British warships were clad with the latter, but later the superiority of the Krupp product was universally recognised and adopted in British ships. Although we have barely touched upon the remarkable life and work of Krupp, yet we can draw certain important conclusions from it.

In spite of the fierce energy which he and his organisations devoted to the armament problem, in spite of unparalleled assistance in finance and facilities from the State, it took years to solve most of the gun problems which arose. Six years passed between Krupp's decision to improve the field gun after the Austrian War, and the satisfactory tests on the new type which emerged from this work, and which re-armed the German artillery. The period of evolution of the K.C. armour plate, on which millions were expended, was between twenty and thirty years. Periods of five and six years were involved in bringing to a manufacturing condition such items as the breech-loading mechanism and the spring recoil device. His great works would labour for two or three years in producing a gun of a known existing type, say one of his heavies, but simply with an increase of calibre and weight. The lag in production in peace was great

even under such ideal conditions, and the question before us is a simple one. Where would the German heavy armament have been in 1914 but for this intensive and amazing Krupp activity of fifty years or more? What would have been the standards of heavy armament in other countries but for the fierce competition which he stimulated between the various armament groups? How far would it help to remove war from reality if we could limit these unleashed forces of armament development under a definite policy of agreed control, instead of unreasoned and chaotic activity to grotesque limits?

Without hesitation we can say that the time characteristics of gun development and allied armament fed from the same factories in times of peace are encouraging from the point of view of disarmament. They are not such as to present grave obstacles, and the suggestion of lightning conversion is far from reality. They support the conclusion, which seems to be emerging in our study of armament, that even to-day production is of such a nature that armament limitation, if framed on rational lines, can be effective.

SHELL

The projector is not an effective weapon without the projectile. The gun is useless for war without the shell. It is the conversion lag of both which governs the availability of guns for war so far as disarmament is concerned. The consumption of shell of all calibres and types during the war ran into fantastic figures; the Allies alone consumed over five hundred million. Shell seems to be a relatively simple item of armament production in which countries before the war all possessed technique and equipment, and information regarding lag in production in this field should be of considerable value. Before proceeding to facts and figures regarding manufacture and its bearing on our argument it would be well to remind readers in the shortest possible way of the nature of the modern shell. The general idea is very simple, but not so simple as a metallic envelope or container simply enclosing a mass of explosive which explodes on violent shock. The shell provides a series of explosions or detonations of graded safety and importance, protecting the shell and its users right up to the moment of actual impact, yet designed to give the maximum destructive effect thereafter, and each demanding its own mechanical contrivance, accuracy of manufacture, and standard of design. Delicate mechanical adjustment is necessary between the various parts.

First, at the nose comes the firing-pin, which by impinging on its objective starts the explosive series. Impact causes it to strike the protection primer, which is a kind of cap ; this primer explodes the detonator, usually containing some readily exploded body such as mercury fulminate. The shock from this explosion causes a further explosion in the charge of the booster, which is a long cylinder or tube extending down the centre of the shell, and it is this booster which by its explosion fires the main charge in the body of the shell. The times, quantities, sensibility, violence, and other characteristics of explosion of these elements are carefully graded to give the maximum effect from the main explosive charge.

Before studying any of the detailed operations of shell production in the U.S.A., the general picture of their whole effort is very instructive. When the U.S.A. entered the war they possessed probably about a fortnight's supply of shell, estimating on the rate of consumption in the autumn of 1918. Their plants were totally inadequate to cope with even a fraction of such consumption, but by the end of the war such an effort had been made that the quantities produced were phenomenal. The programme, comprising about forty different types of shell, and taking into account the varying calibres and types of explosive, involved several hundred different articles of manufacture, the assembly of which in the proper design led to the completed forty types. To meet the varied technical nature of the different forgings and machinings an extraordinary variety of firms came into the scheme. They included manufacturers of brakes, pumps, farm machines, wire wheels, bridges, motor-cars, pneumatic tools, pressed steel, sanitary goods, filters, electrical appliances, gas light, rolling mills, sawing machines, lifts or elevators, tubes, brass, and many other companies, totalling about four hundred. Diverse reasons governed the entry of these companies into the shell production field, and their response to the appeal. In some cases they possessed tools which were suitable, or could be readily adapted to some specific part of the shell construction, while in others it was a question of being willing to capitalise entirely new factory equipment, with or without the existence of some nucleus of knowledge, staff, or experience which indicated an element of suitability for the job.

By November 1918 about a hundred million forgings and machinings had been accepted, which was very much smaller than the total ordered. The expansion from negligible output to

these vast quantities was accompanied by inevitable complications which led to long delays in the realisation of programmes. For example, the shell used by the U.S.A. army before the war was very different from the type employed later ; a change-over had to occur from the base fuse to the nose fuse type, which involved the use of adaptors and boosters. These were new features in U.S.A. industry, and presented much more difficulty than had been anticipated, so that shortage of these elements in the programme was the limiting factor. All the belligerents were troubled in their production of shell by changes of design during hostilities, but the U.S.A. were peculiarly subject to this difficulty. It was obviously desirable to have the maximum standardisation of armament amongst the Allies. The French particularly, and the British to a large extent, had by 1917 already developed huge equipment and sources of production of their own types, evolved in more or less logical manner from traditional designs, the French being on the millimetre and the British on inch calibre types. The U.S.A. was faced with the choice of developing its own and entirely new series, or, in the interests of standardisation and interchangeability in the field, adopting the existing standards of an Ally.

Now in May 1917, with the entry of the U.S.A. into the war, there was a great impetus to relieve the Allies of productive burdens by employing the vast industrial facilities of the U.S.A. Questions of standardisation had not been fully sifted and agreed. Vast orders were placed on the basis of existing types : for example, nine million rounds of 3-inch shell and shrapnel. But the arrival of the French Mission resulted in the modification of such orders, pending a decision as to the changing of calibres to adapt to French systems. Gradually the importance of changing the 3-inch to the 75-millimetre and the 6-inch to the 155-millimetre calibre was seen, and the decision was made in June 1917. Even with the calibre question settled, there remained the question of shell type, in which the French varied from the British and American practice. The differences were not only in design, but in metallurgical technique. Drawings and technical reports had to be brought over from France, and manufacturers pointed out the delays which would ensue if French specifications were rigidly adhered to. They called for drastic heat treatment and hydraulic testing, ample facilities for which did not exist in the U.S.A. Finally a compromise emerged, based on the maintenance of ballistic standards of design, but changing metallurgical

technique. French dimensions and shell were adopted for the 75- and 155-millimetre calibres, but American manufacturing practice was retained, which proved very satisfactory.

There were very few factories able to turn out complete rounds of ammunition, but many capable of making one or other of the shell components. In anticipation of the enormous future orders which might come, the policy of getting as many factories as possible into production was adopted. But to reinforce the starting and end points, i.e. the steel forgings and raw materials and the assembly of components, the Government took over the control of raw materials and concentrated on assembly into finished shell. We get an idea of the waste and difficulty in such an effort by considering the actual results of the really successful American effort. Although about twelve million high explosive shell for 75-millimetre guns had been machined by the end of the war, only three million had passed inspection. In some types, of course, the ratios were higher, but no ordinary enterprise could live on a basis of this sort, and on the standards of peace these wastages would mean ruin in the life of an individual firm, and a deadly reduction of the standard of living if generalised for all industries in the peace activities of a nation.

Owing to the life history of the individual shell being spread over the passage of its components through various works, from the raw materials to assembly of the parts into a finished shell, concrete examples of the shortest times into which this development was pressed are rather difficult to obtain. The period varied from about five to twelve months, the shorter times being realised in cases where one works took charge of a large number of the components. This was the exception. We had such favourable cases in England at the Hecla Works of Messrs. Hadfield's. In this case, plant installation began late in October 1914 for 4.5-inch H.E. shell, and the first deliveries took place almost exactly five months later, with two or three further months before the steady programmed output was reached. Again, the 18-pounder shell production from start to first delivery took six months. On the other hand, the case of a National Projectile Factory is interesting, as it represented a wider and more varied programme. Started in September 1915, the first shells came forward nine months later.

As in the case of other types of armament, the manufacturing problem was aggravated and the time lag increased by technical problems calling for solution, and by the changes which they imposed upon manufacture when they were solved. The urge

towards the more accurate stream-line shell is a good illustration. A rough general description of the pre-war modern shell would be a metal cylinder with square-cut base and bluntly rounded nose. To engage the rifling channels of the gun and cause the shell to whirl, and thereby keep a straight course, neutralising the tumbling tendency, the shell was provided with a circular band of copper. As their shell interests and activities increased, the U.S.A. found cause to criticise the accuracy of certain combinations of gun and shell. Expert investigations by mathematicians and physicists showed that the force on the projectile distorted the copper band, causing a flange which did not offer uniform resistance to the air, resulting in short range and loss of direction. Much patient work led to a redesigned band. The same investigation showed the great benefit of the so-called "boat-ended" instead of square-ended shell, and led to the American streamline design, with slightly tapered sides at the back, elongated nose, and sharper point. The result was an increased range, in one case amounting to two to three miles, with greater accuracy, and therefore very important economy in the operation and use of heavy shell. Recollections of any big shell dump in France will remind the soldier reader that the stream-line type was fairly widely adopted. When we remember that for one complete round of artillery ammunition between fifty and a hundred dimensions must be accurately gauged, and the gauges employed require about twice as many master gauges, we realise how even the slightest changes in design applied to existing production of shell must hamper it and cause months of delay.

The fact that shell production on any scale involves serious time lag is illustrated in a very general way by the differences between American and Allied production. The American effort was aimed mainly at satisfying the needs of her own artillery, and it is recorded that some twenty-nine million shell were accepted. But in England in the third quarter of 1918 nearly sixteen million shell of various calibres from 18-pounder up to heavies were produced, and it is estimated that the British army and navy fired a total of nearly two hundred million shell during the war. The average weekly expenditure in France by the British army increased from about two thousand tons of shell at the end of 1915 to over one hundred thousand tons in the corresponding period of 1918, a colossal expenditure of chemical and metal, the latter, it is said, including a total of about five and a half million tons of steel.

But the time periods involved in shell-production are not limited to producing the metallic parts. They are seriously influenced by the problem of shell-filling. This was a fairly quick operation once it was standardised, but a nation not already equipped with machines, factories, and trained labour for shell-filling has a long and weary road to travel before it can undertake that operation on a scale consistent with modern hostilities. A real difficulty of shell-filling—introducing the explosive into the metal shell—is the danger of explosion. Great tonnages of explosives, handled up to that point in bulk under highly standardised conditions, now have to be split up into hundreds of thousands of small quantities, each one of which is subject to the common risks of the explosive and has to be handled separately. Should any one of the small shell charges explode, it is exceedingly difficult to localise the result, which may spread to the whole works and become a great catastrophe. This imposes all kinds of conditions in factory and machine design and in works organisation. The shell-filling operation at once introduces an enormous multiplication of the standard explosive risk, and we know from terrible experience during the war what that risk was. Apart from the carelessness of an operator, there is the danger from foreign matter and grits on the metal parts of the shell-filling machine, and, in addition, the operation demands the greatest precision owing to the possibility of loading defects, such as air-spaces, non-uniform distribution of explosive, which tend to make the shell a danger to one's own forces. In meeting these difficulties and satisfying these standards, various phases of development, all involving time, had to be passed through in all the fighting countries. Not only was the mechanical design of the shell-filling unit continually changing, but the different mechanical methods imposed different standards upon the explosive itself, which carried the delay right back into the chemical factories. Cold-loading, hand-tamping methods required the explosive in a definite particle form, and the dangers of this method led to the use of hot cast explosive, which brought in difficulties of supplying the explosive to a definite setting quality, and of keeping it uniformly hot prior to pouring. In the case of some shell, pouring had to occur in several operations to prevent the formation of dangerous cavities. Inspection of any shell-filling plant during the war gave the impression of an easy, smooth-running operation, which could be turned on almost at will and expanded without delay at the outbreak of war, but this is very

far from being the case. Shell in manufacture and filling is subject to the same long time lag, and has the same bearing on the disarmament argument, as the other forms of war production which we have examined. The position is well summarised by a quotation from an interesting munition record[1] : " It takes the best part of a year to produce shell on a manufacturing scale when you have to start from the very beginning : that is one of the lessons of the whole munition effort 1914–18 which have been forced home on us."

THE MACHINE-GUN

At some later period in the history of the world, when mankind looks back with amazement, incredulity, and horror at the efforts which his ancestors made to devise means of self-destruction, his attention will be focused on the machine-gun. This is probably the most terrible and devastating weapon which has ever appeared. The underlying idea is very simple, and needs to be appreciated by everybody so that they may realise its ultimate conclusion should technical war development remain unrestricted. The machine-gun originated from the fusil, or rifle in its later form, a weapon in principle which fired a metal projectile propelled by explosive. Both in the soldier's training and the technical development of the modern rifle the object was an instrument of long range and great precision. It fired at relatively long intervals, with a limited objective, but the tactical use of the weapon by a number of soldiers in rapid fire gave the effect of a large number of small bullets covering an area with higher projectile concentration. Parallel with this there arose and developed the idea of reaching the same end with one weapon, giving the effect of a large number of rifles operated almost simultaneously from one spot. This led, by a long, interesting process which we discuss later, to the mitrailleuse, or machine-gun, in which, although precision was not abandoned, the main object was to cover an area with great density of projectile. At first, the weight and other characteristics of the weapon made it impossible for one man to operate it, and a crew was required, but gradually, with improvements in the sciences and industries on which this weapon is based, the ultimate objective is being realised. We can forecast a weapon not much heavier than the modern rifle, able to be handled by one man, firing an enormous number of

[1] *The Great Munition Feat, 1914–18*, by George A. B. Dewar.

projectiles in a short space of time, and giving to one man the power to kill or mutilate thousands. No soldier will ever forget his first sight of No Man's Land in front of a machine-gun emplacement. The cone of hundreds of British dead, a field of motionless khaki in front of the barbed wire beside the Lens road at the Battle of Loos, is a thing which I shall not forget. As the gun traversed and returned across its field, successive lines of advancing men would drop, never to rise, as though in a carefully prepared movement. Gun elevations were adjusted to cause the maximum number of fatal wounds. No civilian or soldier having seen or experienced the deadly combination of wire entanglements and machine-gun fire can retain that vague neutrality to war which was the main road along which certain forces moved towards the great catastrophe of 1914.

However, to pursue our study, what are the cold technical facts surrounding the production of the machine-gun? It would be quite easy to conclude, in the matter of this weapon, that its production from certain elements of standard engineering plant would have removed it from those long development stages and production lags which have such important bearing upon disarmament possibilities. Most of us have heard or read the misleading suggestion of overnight production of machine-guns in sewing-machine factories, but a close examination of actual events in either Germany, France, England, or America forbids such a conclusion, and the facts of the American position are most readily available. The bulk production of machine-guns was complicated and hindered, practically throughout the war, by constant changes in design. The general tendency to move from a policy and a type of warfare in which a limited number of special units operated heavy and cumbersome types, to a condition in which much lighter types found dense employment on army fronts, and within infantry units, apart from special corps, involved constant adjustment in design, and modification of supply contracts, with the inevitable delays which follow. This cause of lag in armament production has been referred to before, and I cannot reiterate too strongly that it is not an unusual feature, with incidental bearing on my argument, but a factor which would always arise and cause delays when a relatively disarmed country attempted rapidly to develop a formidable armament equipment.

Prior to 1914, it was the Balkan War which provided the data from which the future importance of machine-guns could have

been forecasted. It seems quite clear that military experts in all countries were divided in opinion, and that unanimity was greatest in Germany, so that country was the most prepared to exploit the weapon when war broke out. I think I have already gathered a sufficiently representative body of facts to claim without denial that if Germany had been content to rest upon this wise opinion, it would have had little incidence upon her success at the outbreak of war, owing to the inevitable delay which would have arisen in reaching a state of bulk production, but, quite properly in relation to disarmament conceptions existing at that time, Germany moved in the matter to such an extent that her armies entered the field vastly better equipped in this respect than any of her enemies. It is reported that she actually possessed fifty thousand Maxim guns when war broke out.

In a later chapter on the control of the new agencies of war I have described the evolution of the machine-gun, which actually covers more than one hundred years. The gun invented by Sir Hiram S. Maxim, used in the Boer War, was probably the most successful of the various pre-war types. Not only was it taken up in England by the Vickers Company, eventually becoming the well-known Vickers gun, but it was the backbone of German machine-gun equipment at the commencement of the war, and the U.S.A. had started its production in the works of the Colt Company about 1903. Campaigns and tests prior to 1914 had shown the basic disadvantage of the Maxim gun and its competitors. The tremendous heat developed by continuous firing necessitated cooling systems which no amount of ingenuity had been able to provide with the necessary efficiency without great weight. Water-cooling was essential. Air-cooled types had been devised, and were generally unsuccessful, but during the three years or so which preceded the entry of America into the war there was at least one important newcomer, the Lewis gun, in the range of machine-guns, which was the well-known air-cooled gun, weighing only 25 lb., as against 35 to 40 lb. for heavier types. This, although exceedingly mobile, could not be fired for sufficiently long periods to supplant the less mobile Vickers gun. During the war it was a common occurrence for one Vickers gun to fire between ten thousand and twenty thousand rounds per hour without a stoppage, whereas the air-cooled type required a change of barrel for every five hundred rounds. Thus, in the spring of 1917, America found herself with no fixed machine-gun policy, but with some nucleus of manufacturing facilities and

experience, mainly due to orders for the Allies. There were two factories in production, one completing a large order of about twelve thousand Lewis guns for Britain and Canada, and another which had supplied the Russian Government with an old type of Colt machine-gun. In addition, the Colt factory was equipping itself, and had started production of several thousand Vickers guns destined for the U.S.A. and for Russia. For some time America had been studying the ebb and flow of Allied technical opinion in its bearing on her own machine-gun position, and the result was a decision to produce four types of guns : the Browning and the Vickers in the heavy class, the Lewis in the intermediate class, and the Browning light automatic rifle in the feather class.

The effort made by the U.S.A. towards machine-gun production was fantastic in its intensity and result, and the speed of production is of the greatest interest. We cannot do better than follow in a very broad way the progress of some of the chief Companies. Within a week of the outbreak of war—the entry of the U.S.A. early in April 1917—a contract was placed for 1,300 Lewis guns with the Savage Arms Corporation, which company had nearly completed the supplies mentioned above. The contract was heavily increased early in May. There had been some changes in design, and considerable improvements. The first deliveries under these contracts began in December 1917, some eight months later. By May 1918 the company had produced 16,000 Lewis guns. The Marlin Rockwell Corporation had previously produced other forms of machine-guns for the Russian Government, and, after some months of warning, substantial orders for Browning aircraft machine-guns were placed in September 1917. Supplies began to come through in January and February 1918, and by May some 17,000 were available, increasing to 38,000 by October 1918, when the factory went over to Browning guns. The same company had received contracts in September 1917 for 20,000 Browning automatic rifles, supplies starting in June 1918, and by July some 6,000 had come forward, and 16,000 by the time of the Armistice. In the case of the other great companies producing the different types of machine-guns, the same form of development was experienced : a production lag between contract and first deliveries of from six to eight months, substantial deliveries two or three months later, with an enormously increased rate of output thereafter. The reasons for, and the characteristics of this type of production are well known : the early period of installing or modifying equipment, organisation of

staff, standardisation of drawings and gauges, sub-contracts farming out accessories in some cases, the gradual assembly and testing of component parts getting nearer to the first deliveries of the finished article, followed by those deliveries, and then a great sweep upward in the curve of increased production. The cumulative effect of this process will be realised from some of the astounding American figures. Although the great effort, the placing of contracts and the warning of companies, began in May 1917, and substantial deliveries of the new types were not in time to equip the American division which sailed in May and June 1918, or only in time partially to equip them, yet by the Armistice some 52,000 Browning automatic rifles had been produced, about 20,000 Lewis guns, about 38,000 Marlin guns, and about 42,000 heavy Browning guns, a total of about 150,000—probably more than twice the world's equipment in 1914.

This effort, to be appreciated, must be compared with the British total of 240,000 produced during the whole war period. It is reported that at the end of the war the U.S.A. had on order from their own plants about half a million machine-guns of different types, and it is quite clear, from the figures available, that had the war continued, the American army would have been able to employ an unprecedented density of all types of machine-guns in the air and on land against Germany. From the point of view of disarmament, machine-gun production provides no exception to the general conclusion. A country not specifically preparing for war, with a generally peaceful policy, and under such circumstances, or under a disarmament scheme possessing very little equipment for the production of this weapon, cannot spring to arms in a few weeks, or even in a few months. It is a question of a long-time lag, even with this highly standardised, well-known, and relatively simple weapon.

To illustrate the technical difficulties which arise in a development of this sort and add to the intricacies of the situation, I would mention two modifications of the machine-gun—the aircraft and the tank gun. The war had produced a machine-gun suitable for aircraft which could be synchronised to fire through the rapidly revolving blades of the propeller. This was the first, or fixed type, of which the best example was perhaps the modified Vickers gun. There was also need for a very flexible form of machine-gun mounted on a universal pivot and able to be aimed and fired by the observer in any direction. The U.S.A. had developed its heavy Browning gun for the fixed type, but could

not proceed with it in view of the delays which would have been involved. But American inventors had also improved the Marlin gun for such uses, and, as factory equipment for its production was in a much more available condition, a decision was made in that direction. Research work still remained to be done, however, to develop the high-speed hammer mechanism and trigger motor for synchronising with the propeller. Co-operation between the Government and the Marlin Company, after intensive work, and the rejection of many special models, led to the production of the Marlin aircraft gun, which met with surprising success. Ordinary land machine-guns were not necessarily satisfactory for tanks. There were various difficulties associated with two main causes ; first, the high concentration of noxious gas, mainly carbon monoxide, which poisoned the occupants of the tank, and, secondly, the mechanical adaptation of the gun. These points all involved features of new design, field testing, and building of models, which introduced many months of delay in the evolution and availability of satisfactory types.

THE RIFLE

The old military maxim that no nation can impose its will upon another through military action without final decisive action by infantry, irrespective of what science may produce in the way of new weapons, is still stoutly upheld in the best informed military circles. The main infantry weapon is the rifle, and, although it may in the future be replaced by some super-weapon, say a hybrid between a rifle and a machine-gun, we are not concerned with this at the moment, but with the position to-day. The rifle is therefore of considerable importance in any discussion on armament limitation. If, at any given point in a crisis between nations, military staffs are asked by a Government whether the nation is prepared for war, the existing capacity in terms of rifles must be a consideration almost as grave as the number of trained combatants. Without a satisfactory rifle situation no decision for war could be given in answer to such a question, which is the most serious one that any staff has at any time to face.

It is unfortunate that the war experience in the different countries does not provide so much direct information on the lag in rifle production as it does, as we have seen, in regard to other important branches of armament, but the reason for this is clear. All the chief countries had quite substantial factories and facilities

for rifle production before the war, and, as the rifle is a relatively small unit of production with a long life-period in use as compared with other weapons, with highly standardised manufacturing processes, the big margins of productive capacity over numbers in use were not so necessary as with many other forms of armament. This brings out the great importance of strict limitation of rifle-producing capacity under any scheme of limitation which controls the number of trained combatants. At the moment we are not concerned with this point, but rather with the speed of development of production, on the assumption that a nation starts from a strictly limited manufacturing capacity. It will assist us to get a general idea of what is involved in the production of a rifle.

Few people realise the great number of separate parts, each of which has its own standards of accuracy and finish, and presents its own manufacturing problem. The British Lee Enfield contains about one hundred and thirty different parts, and the American Enfield has about the same number, the soldier being able to dismount his own Enfield into eighty-six separate components, some of which were themselves built up of several items. The number of gauges, jigs, dies, and tools for the manufacture of all these parts runs into thousands, and the time lag in rifle production is mainly concerned with the manufacture of these components, the assembly being a fairly rapid operation. The fastest mechanic in the American factories manufacturing the British Enfield rifle had a record, it is said, of fifty rifles assembled per day, and, with the modified American Enfield produced later, the figure reached two hundred and eighty rifles.

Consider some of the components for a moment. The butt and two other parts are of wood, a special walnut, for which in 1914 the practice was to season it for three years at definite temperatures with the object of neutralising all further movement in the wood under strenuous service conditions, and in all climates. This, of course, had to be speeded up, but the supply remained a source of anxiety for a long period. The barrel alone has a long life period in the factory. It has to be forged, drilled, turned, ground, bored, set, and rifled, involving nearly a hundred separate machining operations, some of which are quite lengthy. The body of the Lee Enfield, in moving from a rough forging through its one hundred and fifty or so operations, finishes up with a loss of four-fifths of its original weight. The problem therefore rather takes the shape of a conclusion as to the time lag involved in

producing a steady and adequate stream of over a hundred very accurate components ready for assembly. I think it can be said on the basis of volumes of evidence from peacetime engineering industry, and from war experience on articles such as machine-guns and light ordnance, that, starting with a plant well equipped with general services and the right type of small tool, the period is at least six months, but, starting from foundations, it would be quick work to get a steady supply of all components in big volume in less than twelve months.

After all, the British position in 1914 provides fairly solid evidence that there is no possibility of a rapid appeal to, and response from, peacetime industry in order to obtain an immediate or quick supply of rifles on a very large scale. In England, steps were at once taken in 1914 to increase the output of the existing factories. The Birmingham Small Arms Company had long rifle manufacturing experience—they made great quantities during the South African War, reaching an output of between two and three thousand Lee Metford rifles a week—but during peace the rifle capacity had fallen so that in 1914 the possible weekly production was about one hundred and thirty-five. Now there was no assumption on the part of our armament departments and specialists in 1914 that this great company would immediately, or even very quickly, be able to cope with the anticipated increased requirements, for orders were at once placed with the great American companies—the Winchester Company and Remington's, for example—to spread the burden of production while the home manufacturing capacity was being organised. We could measure the task of the B.S.A. Co. when we realise that they finally reached a position in which they were producing nearly half a million rifle components each week, involving some fifteen million machining operations. The greater part of a large factory had to be set aside for manufacturing gauges and small tools.

The American annals of rifle production provide us with other good general indications. The Springfield rifle was the official weapon of the American army before war broke out. It had a wonderful record in international shooting competitions, and was regarded in America, and also in quarters outside it, as being superior to the Mauser or the Enfield, and, in fact, to practically all other pre-war types. The 1903 model had been built in the Springfield armoury and at the Rock Island arsenal, and although it is true that in 1917, when America came into the war, her production of Springfields was not great, yet this was a case of

possessing definite capacity, complete and thoroughly approved design, and all the necessary experience from many years of operation. Under these conditions, and with unqualified and strong official backing, one would have thought that by far the simplest course for the U.S.A. in 1917 was to expand the production of Springfields. There could have been no other course if there were anything in the idea of "overnight" or rapid conversion in the manufacture of this type of light armament. But the manufacture of Springfields was rejected. The view was taken by those who knew, on the same grounds as those I have outlined above, that months, or even years, would have been necessary to build up the requisite manufacturing capacity for Springfields, and that such a policy could not have equipped the American armies in time. Actually the American Government turned to the five great American concerns engaged in the manufacture of rifles for Russia and England. These had been through the long development period for the Enfield rifle and could make the latter in sufficient quantity for America. But a further grave decision on policy faced that country, for her arms specialists were not satisfied with the British Enfield, and insisted on certain modifications. It was again realised that even changes in an existing type, thoroughly backed by factories and equipment, would mean months of delay, so much so that the American Director of Munitions wrote: "The decision to modify the Enfield was one of the great decisions of the executive prosecution of the war—all honour to the men who made it." The gravity of this decision was proved, although its wisdom was not questioned, by the fact that although instructions of great urgency were issued in or before May 1917, production did not start until four months later. We can again conclude, on the basis of substantial experience and evidence, that the rifle does not provide an exception to the general rule which is emerging; its manufacture is subject to the same characteristics and delays in development, and it provides no peculiar difficulty in disturbing the symmetry of a disarmament scheme dealing with productive capacity.

SMALL ARMS AMMUNITION

This, the well-known S.A.A., is of course necessary before the small arms themselves, the rifle, machine-gun, or revolver, can actually operate as weapons. The production of the latter controls the use of the former, and, in the matter of armament

potential and its bearing on disarmament, the weapon and the projectile must both be considered. A casual survey of peacetime facilities in relation to possible war as regards S.A.A. would lead to the conclusion that here, if anywhere, quick conversion and ready supply would be typical. One would have thought that sporting requirements in peace, supplies for recent wars, and in general the basic nature of this element of armament, would have produced a situation from which very rapid expansion was a simple matter, but in America this was by no means the case. It is true that before the war the standard product, the .30 calibre cartridge, had been produced in large quantities, and also that during the years of America's neutrality large quantities of S.A.A. had been supplied to the Allies. These, however, only contributed to America's later needs in the matter of experience, and much less as regards capacity, because the calibres and types were not the same. In 1917, therefore, the only American plant equipped to produce large quantities of her own S.A.A. was the Government Frankford arsenal, but, whereas the past was concerned with millions, the war demands which arose were in billions. For some years before the war America had adopted a policy of encouraging the manufacture of official ammunition in private factories. Small annual orders, each of about one million rounds, were placed with various private concerns. The idea, of course, was to spread the necessary experience, acquaintance with designs, and certain tools and control accessories, such as jigs and gauges, thus making for rapid expansion in an emergency. But even these precautions failed to meet the case, and it was rapidly decided that a much more drastic solution was required. The organisation of a special group of manufacturers was taken in hand very early, after full consideration and rejection of the possibility of expansion in official arsenals, with such effect that, whereas the prewar production is said to have been about a hundred million rounds per annum, the new group increased this rate of output by more than twenty times. But to reach this result each plant had to develop entirely new units of trained personnel on a much larger scale than hitherto. Exact information on the delays involved is not available, but many months elapsed before the tension was relieved.

The experience of the Frankford arsenal is indicative of the delaying factors which in some form or other invariably arise to clog these great movements of armament expansion in a race with time. Early ammunition sent to the U.S.A. forces in France

showed a tendency to misfire. The trouble was apparently traced to the primer which controls the propellant charge. The primers from the Frankford arsenal had given steady and satisfactory results in many years of peace, but it was found that in the rush of war production the chemicals in the primer, through inadequate drying, were developing acid corrosion of the metal parts, leading to misfire. This was so serious that some six months' production, probably amounting to over fifty million rounds, had to be withdrawn from use. We can imagine the importance which such a defect would have assumed had the U.S.A. adopted a policy of concentrating all of its S.A.A. manufacture in one arsenal, and had this trouble developed unsuspected over the whole production.

The vast quantities involved also led to difficulties as regards materials, particularly those of the bullet. The standard construction was a jacket or outer cover of cupro-nickel enclosing the lead core. Cupro-nickel is an alloy of copper and nickel of relatively recent introduction, although Germany had considerable experience in its uses and manufacture. The properties of copper-nickel alloys which recommend them increasingly for peacetime uses do not coincide in all respects with those for war. These alloys were being developed before the war, and have since made great strides as decorative resistant metallic surfaces for domestic use, or in building or furnishing. They can be made relatively ductile, and are amenable to the standard operations of the metal industries, such as sheeting, extruding, thereby enabling various shapes to be made, as those required for shop-fitting and domestic appliances, such as refrigerators. Coupled with this, the nickel content results in very high resistance to the usual corrosive agents. Their capacity to take a very high mirror polish also promises a great future for the alloy. But its chief value as a bullet coating lies in the combination of sufficient strength to prevent the deformation of the lead core in storage and handling, with adequate softness to preserve the rifling of the gun barrel with the passage of many thousands of bullets moving at high velocity. Even in Germany, which was well ahead in the development of these particular alloys, a shortage had already been felt, which had led to a new type of bullet with a double coating of copper, covering steel, the latter giving strength and the former softness and barrel protection. This line of research was by force of circumstances followed in America, and the copper-steel bullet would almost certainly have come into use had the war continued.

The tracer bullet is interesting as an example of yet another armament feature in which considerable research was required, and therefore much time elapsed after the outbreak of war before it could be used. Although most readers will remember this bullet, very few will have troubled to become acquainted with its details. The object was to design a bullet specially suited to attain an individual objective, such as in aircraft combat, where great speed of both opponents made it essential to record a hit in minimum time, and with the least number of shots. In such combats, bullets not attaining their objective were wasted, whereas in many forms of land warfare there was a very good chance that a second, unsighted objective would be attained, and also more opportunity to retrieve an error. The idea, therefore, was to make a visible or tracer bullet which would enable very rapid adjustment to any initial errors. The fact that the bullet was visible much facilitated the task of firing from a moving weapon at a moving object, and tracer bullets were therefore mainly employed by aircraft machine-gunners, being inserted at intervals in the belt feed. The shell of the bullet was of copper-nickel, containing the lead core and a rear chamber with a small aperture to the atmosphere. In this chamber was a chemical mixture which burnt with such a bright light that it was even visible in strong sunlight and against the worst backgrounds. One such mixture contained barium peroxide and magnesium, which was ignited from the cartridge flame.

The tracer bullet, the incendiary bullet, and the armour-piercing bullet, and their combinations, were all matters of investigation, requiring many months of laboratory and field work, with the further delays in reaching and standardising the new processes of steady bulk production.

CONCLUSION

We could go on describing the production characteristics of other forms of normal armament and their accessories, but we have probably dealt with sufficient for our immediate purpose. We have certainly not excluded any type of sufficient importance to interfere with the stability of a disarmament scheme by its own individual use apart from other weapons, nor have we consciously excluded any important type which is not subject to the same general conclusion as regards conversion lag. It remains to point out what must, in fact, be clear to all—that you cannot

make war in the sense of our discussion with one weapon alone, and therefore it is not a question of measuring the security of disarmament by the conversion lag of one or a few weapons. We have got to take into account the integration of all these elements of delay over the whole of armament production necessary for large-scale hostilities, and to realise that in a great productive effort the different sections interlock and react at all points from raw material right up to the transport of the finished article. The practical conversion lag relevant to the outbreak of a great war, or, conversely, to schemes for its prevention, is much longer than that for any single item. Again, extremely rapid conversion in the case of one armament type, however important it may be—say the machine-gun—would have no practical bearing if the campaign required, as it would to-day, ample quantities of medium and heavy guns whose production involved a much longer delay.

From another viewpoint, the recent statement of the chairman of a great armament firm simply confirms our general conclusion. Commenting on the policy of the firm with respect to the effects of disarmament, he said : " We cannot ' turn guns into ploughshares ' without scrapping practically the whole of the plant required for the production of guns, and substituting for the workers accustomed to gun-production other men trained from youth in the manufacture of ploughshares. In that aspect of the question I can speak with authority." These comments could apply with equal weight to the converse process of turning the ploughshares into guns.

It is, I think, a fair conclusion, faithful to the evidence available, that the conversion lag in the production of any single item of normal armament is real and substantial, rarely less than six months, often much more, and the effective lag for a representative volume of adequate types of armament would be not less than two years to spring from, say, the British to the German armament position in 1914, even in the very few countries industrially equipped to tackle such a proposition, which for most would be a physical impossibility.

Indeed, it would appear that in regard to the evidence which has been brought forward from the war activities of the U.S.A., we have erred, if at all, on the side of caution. It seems that perhaps we have not paid sufficient attention to the time lag involved between the availability of armament supplies at their individual factories and their appearance in an organised army. This is abundantly shown by the official opinions expressed by the

delegation of the U.S.A. in the report of the Preparatory Commission for the Disarmament Conference at Geneva in December 1926. The question, broadly, related to the national resources supporting official forces which needed to be brought into the scheme of limitation. Some of the nations were making insufficient distinction between those elements of war potential which would have bearing upon the possibilities of surprise and outlaw attack, and the great mass of more distant factors of national potential, which it is difficult and unnecessary to deal with under disarmament.

In the controversy the U.S.A. expressed forcefully and clearly the following view : " In the opinion of the delegation of the U.S.A., the crux of the whole question of land armaments is involved in the question of trained reserves and the reserve material with which to equip these trained reserves. A nation possessing an adequate trained reserve, with the material to equip it—arms, etc.—and with the necessary ammunition in stock, can begin fighting offensive battles immediately on the outbreak of war. A nation that does not possess an adequate trained reserve, and material in stock to equip it, but which must train its personnel and convert its resources into arms and equipment, will not only be unable to engage in offensive battles, generally speaking, for a minimum of a year, but also will run the gravest danger of defeat and disaster during that period.

" It is generally accepted by all military men that at least a year of training is required to produce troop units, including divisions, capable of successful employment in offensive battles. The experience of the U.S.A. has also demonstrated that industrial resources cannot be converted, and mass production of armaments take place, in less than from twelve to twenty months.

" It should be borne in mind that for more than a century there has been a continuous increase in both the quantity and complexity of material needed for the successful conduct of either defensive or offensive war. The time has long since passed when it was possible to produce after an emergency began the supplies and equipment necessary to arm, equip, and maintain soldiers in the numbers required in modern war. This was clearly demonstrated in the World War. In spite of the fact that the United States was in possession of great national resources and of a great industrial plant, and expended almost unlimited funds, our Government was forced to depend upon our Allies to supply and equip the forces maintained on the firing-line. This dependency extended to every item of supply and equipment except food and

money, and, to include the date of the Armistice, was absolute in guns, ammunition, airplanes, and tanks. The significance of this may be fully appreciated from the fact that only four cannon produced in the United States during the war to meet its war requirements reached the front before the close of hostilities—nineteen months after the declaration of war. Furthermore, not one round of the expenditure for the most important calibres used by our army in the Battle of the Meuse-Argonne, which ended nineteen months after the declaration of war by the United States, was produced in the United States after the declaration of war to meet its war requirements."

This statement was based on the most complete evidence, and is supported by every fact of armament production which we have examined. I am strongly tempted to reproduce some official statements from that same important conference, which claim facts of production diametrically opposed to the above conclusion, and, so far as I know, finding no support at any point in armament production. The comment that artillery shell and similar projectiles for gas would take several weeks to make is a typical example.

However, and to conclude, no better authoritative statement than that of the United States delegation, reproduced above, could have been found to support the disarmament case and structure which we are patiently building up from first principles in these chapters.

CHAPTER V

THE EXPANSION OF ARMAMENT: THE NEW AGENCIES OF WAR

The Tank : The Livens Gas Projector : Sound-Ranging : The Trench Helmet : Body Armour : The Gas Mask : Carbon : Chemical Munitions : Explosives : The New Chemical Agencies

There is no fixed line of distinction between normal armament and those weapons which are now referred to as the new agencies of war, but there are periods in the history of the world and of its armament when a new weapon may emerge so sharply as to create a new class, a fundamental step in advance of the past. Such a situation was reached when explosives appeared, and one would expect it to recur if at any time armament development reached a peak of activity at the crest of a wave of scientific progress. This would occur, and did do so, when a great war arose in the full flood of our modern scientific era, and we have at the present time the most complete example of this combination in the history of the world.

In the last chapter some characteristics of the production of normal armament were dealt with, and in this I want to discuss the new agencies of war from the same point of view, including in that class some weapons which might be regarded as normal armament, but possessing very novel features, embodying in a marked degree recent applications of modern science. I propose to work from these types, such as the tank, to the more orthodox new agency—chemical warfare. As I cannot assume that all my readers will be acquainted with the details of these new weapons and appliances, it would be wise to allow me to digress here and there, and as shortly as possible describe essential features.

THE TANK

There has been much confusion as to the origin of this most interesting and important weapon. The situation becomes much clearer as soon as we distinguish between the claims to the technical as contrasted with the military initiative. Technically,

the tank is not one invention, but many, the chief being the basic novelty of caterpillar traction, which is responsible for the particular type of movement over hitherto unsurmountable obstacles, without which the tank is simply an armoured car. It is doubtful whether the first inventor of caterpillar traction has been finally recorded, but if any single country can claim precedence in developing the idea it is America. With this exception, the British were the technical pioneers of the tank, simply because they were first in the field as regards bulk manufacture and use, and were thereby compelled to devote much thought and facilities towards the most efficient combination of caterpillar traction and armoured car. The first users would naturally strike the first difficulties, and would be better placed to overcome them.

We believe that the first tank was produced in France, but it was an experimental type, and was not employed in war before the British adopted the tank in the Somme battle. All three countries, France, America, and Britain, shared the technical initiative, but the actual credit or responsibility, whichever way you look at the problem, for making the tank a weapon falls to Britain. It would serve no useful purpose to analyse individual responsibility. The British navy was first in the field through the Land Ships Committee under the Director of Naval Construction, and stimulated by the First Lord of the Admiralty, Mr. Winston Churchill. To him must probably be given the credit for the first strong official impulse, breaking through opposition and compelling facilities for active development. He probably saw more clearly and powerfully than any other prominent Englishman in a reasonable position to implement his views, the need of a special form of armoured machine able to overcome the new type of military obstacle, carrying guns to annihilate enemy positions at close range and, in cases, troops to consolidate and hold the objective. In England the tank evolved through a number of rapidly improving types, the first of which were hybrids and the last pure tanks, showing a vast change in design and efficiency. During this period of development the lag in production was very long—as much as fifteen months between approved design and finished tank. Changes were occurring at almost all points. The armoured hull and turret presented a new problem in light armour-plate ; low weight was important, yet they had to pass tests of shots from enemy rifles at almost point-blank range. Heavy tanks were built up much more like ships in a dockyard than motor-cars in a factory. There were some eight hundred

components apart from the engine, and the latter was usually of several hundred horse-power, built to a new standard of great strength owing to the difficulty of springing the tank to satisfy its great weight combined with the heavy strain of its peculiar type of movement in the field. The British moved through at least eight types, all of which were manufactured and used, and each embodying improvements, either as regards speed, man-power, armament, and armour-plate resistance, which had to meet the German development of anti-tank devices, particularly their light mobile guns and the anti-tank rifle, with its high armour-piercing capacity.

When America entered the war the tank position was relatively far advanced, and, although improvements were to follow, the great development lag had already been experienced. The very first use of tanks at the front was in the Somme battle on September 15th, 1916. This was the Mark I, a precocious but not fully fledged machine, with rear wheels, which, from its progress up the main street of Flers followed by cheering infantry, spread the feeling in the battle and through the Allied armies that we were waking from a nightmare, and that a new way had been opened up to a quicker and more merciful victory, but this promise was unfortunately not fulfilled. Manufacture of this form of tank began more than a year before its use, and, as the French had started producing in 1916 and were showing great initiative in the light Whippet type, America found a considerable amount of Allied experience not only on the manufacture of existing types but also as regards the lines of improvement and development. It must be remembered that by April 1917, when American activities really began, we had used tanks extensively in the Somme battle, and in the Battle of Arras. The engagements at Delville Wood, Martinpuich, Thiepval, Beaumont Hamel, and other Somme death-traps, and at many critical points near Arras in April 1917, were for the tank of classical interest and great value. Sharp lessons of success and failure under varying conditions moulded the development of all later tanks.

American experience in tank production has more direct bearing on our argument because it was based on less complicated conditions, and had a fairer start than the British. In July 1917, American assets for the development and manufacture of tanks consisted in certain rough specifications of different forms from Europe, including descriptions of the machines actually used by the British in their great Cambrai drive. It is generally considered

that these tanks established in that battle the tremendous value of the new weapon by achieving a great advance and reaching the distant Bourlon Wood in strength, but this, of course, had not occurred when the designs first reached America. About the month of August 1917, two experimental tanks were decided upon and commenced, while a month later American specialists were making an exhaustive examination of the whole matter in Europe. Complete drawings were sent over before the end of the year, and a French engineer arrived with a sample of the small Renault type, the French equivalent of the Whippet. There was no stinting of facilities, and as a result, and before the year was out, two types were decided upon, and contracts were placed with some thirty factories to manufacture the various tank parts which, assembled in three special plants, were designed to yield a total of at least six thousand tanks of the two types.

The dates of completion are of great interest. The first finished machines were not through until October 1918, more than twelve months after the decision to produce, and the Armistice was signed before one hundred tanks were ready. Altogether about twenty-three thousand tanks were ordered, covering five types of tank from light to heavy, and involving an expenditure of nearly two hundred million dollars. It is claimed that six months more would have witnessed the completion of the first great programme, and substantial progress with new machines. But the important period from the disarmament point of view—the lag between decision to produce and the maturing of bulk supplies—was from twelve to eighteen months.

THE LIVENS GAS PROJECTOR

Most of the cases which we have examined involve the manufacture and assembly of a large number of intricate mechanical parts. It should be valuable, therefore, to examine a new weapon of extremely simple construction, of which the Livens projector provides a good example, and its genesis can be readily understood. Early cloud gas attacks were made by means of releasing toxic chemicals compressed in metal cylinders. Although responsible for a large number of casualties, the method was relatively clumsy, and suffered one serious limitation as a means of attack ; its dependence upon certain combinations of wind and weather. Thus, cases occurred on both sides in which cylinders installed in trenches could not be used for attack for periods of many weeks.

In others, fronts moved forward after attacks in which gas preparation was planned but never actually used—wind and weather conditions were unfavourable—and the vast labour of installation was fruitless. How well I remember such a case; many nights of vast labour, preparing rain-sodden trenches in front of Blaireville, near Arras, in the winter of 1917, hauling in thousands of heavy gas cylinders and accessories along trenches which in places were deep death-traps of mud, installing gas batteries, and the many false attacks, before, one morning, we found the quiet departure of our friend the enemy had rendered all our efforts futile. It was the great retreat to the Hindenburg Line.

Now the Livens projector almost entirely removed these limitations. By its means huge tonnages of compressed or liquid "gas" were projected with sufficient accuracy to cover a large objective, and to a sufficient distance to render possible the use of gas under a wide range of wind conditions. I have already described the critical importance of this weapon in the Great War.[1] As a mechanical device it would appear to possess the essence of simplicity. The projector was a long steel tube of about nine inches diameter, with a closed end which rested upon a pressed steel base plate, both buried and earth supported. The projectile or drum was cylindrical, about two feet long. It was the new mobile gas weapon, giving the effect of a sort of huge gas machine-gun. The cylinders or projectors were installed in groups of about twenty overnight, usually in No Man's Land, rapidly dug and sunk into the earth at the correct angle and alignment. The charge box was simply dropped to the bottom of the projector, and on top of it followed the big container of liquid gas, both resting loosely in position in the projector, the mouth of which usually protruded only a few inches above the surface of the ground and was easily camouflaged. The writer has installed and seen thousands at a hundred yards or less from the enemy front line, the latter not suspecting their existence in full sunlight the next day. Long electrical leads were carried from the detonator in the charge back to a central battery control position, usually in a forward trench or dugout. The charges were fired electrically, thousands being exploded simultaneously by working in batteries and synchronising the discharge of the different units. Within a few seconds hundreds of tons of deadly chemical were flooding an unsuspecting concentration of troops a mile or so behind the enemy line, with poisonous vapours in concentrations which gave

[1] *The Riddle of the Rhine* (Collins).

no chance of escape, and often none of life. An actual case of its use is referred to later.

Late in 1917, the American Ordnance, seized with the importance of the new weapon, decided to produce it. By May 1918 the design was complete. Although contracts for barrels and drums were allotted to powerful manufacturing companies in June 1918, production did not commence until August, nearly nine months after the initial decision was taken. By the time of the Armistice about six hundred barrels were in daily production. The Livens drums or shells introduced difficulties and delays arising from the welding of certain parts. Acetylene and arc welding were tried, but led to such a high percentage of rejected shell through gas leakage that fire welding was resorted to, a process developed in connection with air-tight steel tanks. It was not actually until the Armistice that drums were forthcoming in quantity, owing to welding troubles.

Many months transpired before the Livens projector as a complete idea matured into a finished weapon. It is probably truer to say that the idea itself only really became complete as the weapon itself developed, and as difficulties were overcome. This, after all, is the common experience of engineers and chemists who take a valuable invention from the laboratory stage to the finished processes involved in bulk manufacture. The perfecting of the Livens projector as a weapon available for the battlefield would have involved still longer delays had America been alone in the matter. There is a further stage of development which involves expenditure, time, trouble, and failures before the manufactured armament becomes truly available as a weapon in warfare. This is a point which is so often lost sight of that it is developed later on. I refer to the tests, usually field work, relating to the use of a new type of armament. For example, in the present case it would have been dangerous—impossible, in fact—to employ it on the front before bulk trials had been carried out to ascertain the angle of discharge and zone of impact, variation of explosive charge with range, the safest quick methods of installation, battery systems, and a number of other points which had to be settled in the interests of the troops employing the weapon. When America decided to employ the Livens projector, these points had all been worked out to a high degree on the experimental fields of the European Allies. Even we at the front made our contribution to this, and I well remember surprising the farmers of the little village of Bavincourt, behind the Arras front, by discharging huge

wooden projectiles from early projectors in range and zone tests. Had these aspects of the weapon not been thoroughly explored, it is fair to assume that a period of about six months would have been added to the American lag.

Although still not faced with a case of very quick armament production, we find the conversion lag for the Livens projector considerably shorter than in any case of normal armament—a matter of nine months when design had to be investigated, but of only three or four in the absence of such delays, which might well be the case with this or similar devices in the future. But again we must point out that the projector alone is not a weapon ; it requires chemical and filled projectiles, which introduces other problems to be discussed later.

SOUND-RANGING

In early wars, beginning from primitive times, the human ear was an important factor. Listening-posts were flung out at night to detect the movements in enemy encampments. From the great battles on the plains of France in the classical campaign of Attila against the Roman Empire, in the long history of besieged towns, and in the Napoleonic campaigns, cases arise when the fate of an army or a campaign was decided by the alert hearing or failure of some sentry or listening-post, through their bearing upon the important military factor of surprise. But the nature of modern war, with the increased importance of single units or groups of powerful weapons, has imposed new standards of hearing beyond the scope of the human ear, and has made it necessary to develop appliances enabling us to hear and locate sounds through obstacles, and at much greater distances than were ever before possible or foreseen.

The first important device of this sort employed in the early stages of the Great War was the geophone, a simple mechanism which rendered sounds audible which would otherwise have been lost, and which were communicated by earth vibrations. Essentially, the sound waves were received and magnified in a kind of drum or box and communicated to the listener's ears by an arrangement very similar to the ordinary stethoscope. This was very effective for detecting underground mining operations, enabling prompt counter-mining to be started and contributing largely to the defeat and decrease of trench mining operations. This device was improved by electrical and acoustic research, so

that a series of microphones hidden in No Man's Land, and connected with a central recording mechanism and station, were able to give a great deal of information as to hostile movements above ground, such as raiding-parties, and sometimes important information was picked up through conversations being overheard. But although the transmission of these sound effects was perfected and considerably increased in range, the method and use of the appliance was limited, owing to the fact that some part of the receiving mechanism had to be concealed near to an enemy who was relatively stationary.

Sound-ranging, however, became far more important, and involved much longer research and production difficulties, in regard to the listening instruments devised for locating enemy gun batteries at long distances. The kind of work involved had only been done on electrical instruments of an entirely different nature during peacetime, and there were very few factories and skilled workers equal to the task when the war broke out. Having realised the need of sound-ranging, it was not possible for the munition contracting departments to satisfy their needs by a quick appeal to industry, and much work had to be done. The microphones and accessories had to be improved to such an extent that all useless sounds not related to the objective—say hostile batteries in operation—were filtered out before they reached the central recording instrument. The difficulties will be appreciated when it is remembered that the firing of a gun involves three distinct concussions, each producing sound-effects. The first noise heard by the observer originates from the shell passing over, as the air fills the vacuum produced by displacement. Later the observer hears the gas expansion or explosion occurring at the muzzle, the shell having travelled faster than this second sound. The third sound involved is due to the explosion of the shell, which will be heard by the listener either before or after the muzzle explosion, according to his position. In any case, the sound-ranging machine had to eliminate all except the second concussion, because this was the one occurring in the position of the gun which was to be located. In operation, the sound was transmitted from a series of microphones through several miles of wire to an electro-magnetic needle recording differences as small as one-fifth of a second on photographic tape. The readings from the different microphones enabled the position of the enemy gun to be determined within a radius of 50 or 60 feet. America had two sound-ranging experimental stations, and worked

continuously from June 1917, but many months elapsed before they developed their final type, which was admittedly an exceedingly good one. At different points of the investigation and in manufacture difficulties were met which could not be settled from peacetime experience, and it was only by a lengthy research that they were overcome.

In passing, it is of interest to note the difficulties which arose on similar lines in connection with the flash-ranging method of detecting enemy guns. There was a great shortage of the proper optical glass for the telescopic system, the bulk of the world's experience and production in this matter being concentrated in enemy countries. The struggle in England and America to develop the right forms of glass and adequate manufacture met with great success, but it took much time, which was the essence of the contract, and is the basis of my argument.

THE TRENCH HELMET

Even such a comparatively simple ordnance feature as the trench helmet took much more time and patient development than most of us would imagine. The various steps in the evolution of metallic armour are of great interest. It is often believed that helmets and body armour fell into disuse owing to the introduction of gunpowder and the weapons which used it. Armour, people imagined, could not resist their powers of penetration. Gunpowder, however, was in common use before body armour reached its highest development, and the decline of the latter has been said to date from the Thirty Years' War, when body armour became an intolerable hindrance in the new tactics of long marches for surprise attacks. Since then, siege warfare has always witnessed the return to armour in some form, such as the corselets and head-pieces of the Napoleonic wars, numerous instances in the American Civil War, and the Franco-Prussian War. Eastern armies, e.g. the Japanese, have been quite heavily armoured until fairly recent times. The Great War introduced trench warfare on a grand scale. This was essentially siege warfare, and head and body armour at once became factors of the greatest importance. Of all the belligerents, probably America and Germany tackled this matter most scientifically and with the greatest success. These two countries recognised the specific technical nature of armour. America, for example, not only invoked the assistance of the Metropolitan Museum of Art, where the evolution of body armour

was richly recorded, but brought over from France one of the few surviving armourers. The first helmet produced by the Great War was French, of which first type two million were issued to their army. Although of hasty design, and inferior to the American, British, and German types, particularly the last, they reduced casualties by at least five per cent. Undoubtedly it was this clearly established fact which compelled the other armies to adopt a helmet. The British type could hardly be called a scientific model, lacking the maximum protective area, with its centre of gravity wrongly situated, and vulnerable at the junction of bowl and brim, but it found justification in its ease and rapidity of production by pressing from cold metal. America adopted the British helmet simply as an emergency measure for quick manufacture, but not from any conviction of its superiority. At the same time she remedied an obvious defect which must have struck those who wore the British helmet in the war ; I refer to the lining. Ours was uncomfortable, and seemed to disregard entirely the anatomy of the head. The Americans improved upon our lining, distributing the force of any blow upon the helmet, so that even a deep dent could not reach the skull of the wearer. The linings were produced by peacetime boot and shoe factories, the metal rolled into sheet by sheet-metal and tinplate manufacturers, and pressed into shape by companies experienced and equipped for the work. At the Ford Company's works at Philadelphia the helmets were assembled and painted. The series of operations seems relatively simple, yet it was not until the end of November 1917 that substantial quantities of finished helmets were received.

BODY ARMOUR

The Germans were the pioneers of body armour, and proved its use in positions exposed to high bullet concentration. They used it in critical forward positions in enemy attacks, where the life of one man for a few minutes might decide the issue of a battle. Metallurgical science has made great strides in the resistance of thin sheets of special steel alloys to high-velocity bullets. A sheet of such metal only one-thirtieth of an inch thick can stop a bullet from a heavy automatic pistol at a range of about ten feet. It is reported that the wounds of four out of every five soldiers were such that armour of this thickness would have prevented the casualty, and it may therefore be asked why body armour was not widely adopted ; the answer is found in weight. An entire suit,

taking about two square yards of metallic "material," would impose an intolerable strain upon the ordinary soldier in movement, representing extra weight of twenty-five to thirty pounds, for the German sets for special use weighed about twenty pounds. America developed an armoured unit of front and body plate lined with sponge rubber and weighing only about ten pounds, yet the report from the front on the five thousand sets sent out was not favourable, entirely on the grounds of troops finding the additional burden insupportable. The heavy breastplate capable of stopping machine-gun bullets at one hundred and fifty yards weighed nearly thirty pounds, and was also tried at the front with the same result. Relatively simple articles, such as helmets and body shields, would, of course, be manufactured very rapidly, once standardised, but, even so, no type came forward in bulk in much less than six months, and the research or development period was as long, if not longer. The future, however, would see a reduction in manufacturing period, for the main technical difficulty—rapid shaping or pressing of special alloys and metals—is one in which peace industry will probably make great strides.

Many prominent military authorities after the great battles of 1916 and 1917 expressed the view that the situation had reached a deadlock on the Western Front. They saw colossal expenditure of men and munitions, as in the Somme battle, leading to advances of a few yards, or, at the most, a few miles, coming to a standstill with the previous conditions of trench warfare simply reproduced on a new line. Their views might have been correct, and the deadlock might have become a reality, but for certain external factors which bore no direct relation to the situation on the front, such as the political changes in Germany and the entry of a great new Power, a reservoir of men and material, in the U.S.A. Had this stalemate been reached, the technical aspect of removing it would have become increasingly important, and, apart from tanks, one of its chief objectives would have been the development of body armour to neutralise the defensive and blocking capacity of machine-guns. The Allies were preparing for this situation, but they had a tough problem in evolving body armour which could meet the two standards of being effective and wearable. One of the most promising lines of investigation, to which many months of development were devoted and in which damaging delays would have been involved had the matter become more critical, was the use of silk. This is a surprising application of such a luxurious fibre, and will be new and interesting to many reading

these lines. Silk woven in special ways up to certain thicknesses has a surprising resistance to high-velocity bullets or metal particles. The fact was recognised in early times, for the Chinese widely employed body armour in which thick silk fabric was reinforced with steel scales. Extensive use was made as early as A.D. 600, and although Western warfare largely superseded silk by purely metallic protection, yet there are cases of its use in the West right up to 1870. It was later employed extensively in the Russian army. Zeglin, a Russian, in 1897 developed in the U.S.A. a closely woven silk nearly a quarter of an inch thick which was proof at eighty paces to a 40-calibre lead revolver bullet travelling at four hundred feet per second. In the Russo-Japanese War the Russian officers extensively employed body protection in which thin chrome nickel steel plate was covered on the outside with an eighth of an inch of such a fabric and with half an inch on the inside, which resisted bullets from the Russian service rifle at two hundred yards range travelling at over two thousand feet per second.

Both in America and England this subject was pursued systematically during the Great War, and the British authority, W. A. Taylor, came to the conclusion that silk was more effective than manganese steel, inasmuch as a layer weighing about ten ounces per square foot of silk was as effective as twenty ounces of manganese steel, i.e. twice the weight, both being proof against shrapnel travelling at eight hundred feet per second. Silk had this advantage against moving metal except as regards penetration by sharp-nosed projectiles, such as very high velocity modern bullets and bayonet thrusts. The peculiar value of silk was due to its capacity to deaden the initial impact and rapidly reinforce the resistance by spreading the shock over an area, and this occurred except in cases of immediate penetration by masses with very sharp edges, and suitable contours to follow the edge through the hole made. Thus it was an admirable protection against irregularly shaped metal particles from shrapnel or broken shell, but it had one advantage, however, even in the case of bullets which penetrated, inasmuch as it did not deform them, as penetration through metal would have done, and it thereby simplified the nature of the wound and multiplied the chances of recovery. Should this have become a critical matter in the Great War, or were it to do so in the future, the limited availability of natural silk would of course at once arise, however much we mobilised the silkworm, and it becomes an interesting speculation

as to how far the artificial varieties would meet the same needs. However, it seems to be the general opinion of armour and plate experts that the great strides which are forecasted in the technique of special alloys are likely to produce plate which will be superior in the combination of weight and protection to silk or soft armour. Even in 1920, plate was available which was at least 30 per cent. better for the purpose than in 1918, and since then further progress has been made.

THE GAS MASK

The development of the gas mask by the European belligerents subjected them to more anxiety and delay, probably, than any other item of armament. It was to all intents and purposes an entirely new feature of military equipment, on which there was no direct previous experience, and very little indirect knowledge and facilities. The novel and changing nature of the weapon against which it was intended to protect involved a constant series of changes in design. The crudest form of mask rushed to the front at the time of the first German chlorine attack gave relatively low protection against the one gas which had so far appeared, and practically none against others which were to come forward later. As new gases appeared on the front, new forms of mask came forward in a series of kaleidoscopic changes of design. Gradually, protection countered and overtook aggression, so that finally, instead of feverish activity against the new chemicals already introduced by the enemy, mask development began to cope with new gases which might but had not yet been used. By the end of the war some would say we had reached, and we were at least well on the way towards, a more universal form of protection. When we consider the millions of combatants, semi-combatants, and civilians who had to be equipped with this device, we realise how huge the task would have been had it involved simply the production of one known type of mask. But the manufacturing problem was immensely complicated by the fact that every few months events on the front or discoveries at home compelled drastic modifications in the supply programme, withdrawals from use of vast quantities of obsolete types, and rapid replacements of the standard mask at any given period. The latter must be perfect or it is practically useless.

The manufacture of the gas mask consisted essentially of two entirely different problems, i.e. the rapid assembly of huge

quantities of canvas, rubber, metal, and other elements to produce an article as perfect as possible in design, and the development, manufacture, and incorporation in the mask of the protective chemicals which not only resist the poison gases but allow the wearer to breathe. All this implied the co-operation of specialists and manufacturers from widely different industries and branches of knowledge, to a greater extent, perhaps, than in any other armament feature. The work was done in Europe in relative turmoil, with no respite, under the shock of a series of new chemical offensives, but the American case was different. There the problem could be viewed with a certain amount of warning and the exercise of foresight. It is true that the unprecedented expansion of the American armies and of the required supplies re-introduced some of these difficulties, but, taking all this into account, the fact remains that the lag in development and production was less in the American case, and it is therefore that case which is of such interest and has important bearing on my general argument.

It was in May 1917 that the U.S.A. started their effort on gas masks. Twenty-five thousand masks were required to equip the first American division about to sail overseas under General Pershing. The American Army Medical Service and the Bureau of Mines had been studying the problem for several months from their respective points of view, having before them various reports on European types of mask, representing experience and developments in the war up to that date. Somehow, by a formidable effort, the masks were produced in less than a month, and I remember personally how eagerly they were examined on arrival in Europe, and how, as a result, the American advisers decided to substitute the British mask without delay in the interests of the American troops. This was the first check, and it was not surprising that the formidable American effort to produce in a few weeks an article which had required many months of intensive work by the Allies should not have been entirely successful. The moment we begin to consider some of the technical points we see the force of this remark.

The first line of protection in this mask was more or less mechanical. The whole face was protected by a fabric which compelled the air for respiration to pass through a special canister which neutralised the poison gases. Incidentally, this fabric also protected the eyes and the skin from the so-called vesicants, such as mustard gas, and from lachrymators, or tear gases. Apparently

the fabric in this first consignment was very efficient as a mechanical barrier to gases; for example, it tested well against hydrogen, one of the most penetrating of all gases. Judged, say, by the standards of balloon fabric, it was very good. Some of the poison-gases, however, penetrated fabric by chemical rather than mechanical methods. Stated simply, they were absorbed by the fabric and passed through it in this condition, and were released from the inner face in sufficient concentration to make the mask useless. Thus we know that chlorine, the earliest gas employed, will pass through rubber and alter its properties in doing so, unless the rubber mix is specially devised to resist it. The powerful American rubber companies at once tackled this problem, and they did so very successfully, but this kind of investigation, even with the maximum facilities and the best brains, requires time. It introduces delay, and bears critically upon that lag in production to which I am continually referring, and which is so important in the disarmament problem.

The soldier must be able to see, and therefore the mask must have eyepieces. This was another problem for solution. Glass was too brittle, celluloid too inflammable and scratchable, and other flexible transparent substances too weak and water-susceptible. Triplex glass was decided upon, but this was then in its infancy. Even now, after ten years of investigation and production for motor-car work, triplex glass is very costly, presents difficulties in rapid bulk manufacture, and some of the companies starting out to make it have had trying experiences. Even when triplex was available for the mask, there was the problem of moisture condensation, which clouded the eyepiece. At least two devices were adopted in turn to overcome this. Folds were introduced in the fabric, which could be used to wipe the lens without removing the mask, and later the invention of the Frenchman, Tissot, gave a much neater solution, cold air coming into the mask being made to flow against the lenses and so evaporate condensed moisture. Working out such points as these, and making them fit in with other essential features of design, means much patient work, and, even under conditions of extreme efficiency, deadly loss of time from the military point of view. It would take a volume to examine all the features of the gas mask in this way. There were problems of the flexible hose from the canister to the facepiece ; the mouthpiece was modified many times in reaching the right design ; the construction of the canister and the chemical nature of its contents was a question of deep research. This will

be seen when I deal below with the carbon question. All this gives only a feeble idea of the mass of technical investigation which was being carried out by hundreds of specialists in well-organised laboratories, while at the same time vast manufacture was going on of types which, although approved for the time being, underwent frequent change.

At least ten manufacturing concerns were involved in the production of the first twenty-five thousand masks, which, as I have pointed out above, were finally condemned. The B. F. Goodrich Company manufactured the rubber parts, the American Can Company produced the canisters and assembled parts, the charcoal was burned by the Day Chemical, and activated in the bread ovens of the Ward Baking Company. The General Chemical Company made the chemical granules, another manufactured the angle tubes, yet another the waterproof knapsacks, and so on. The use of British masks by American troops gave a breathing-space after this valuable initial failure. Private contractors patriotically took on their particular burdens in this unaccustomed work under closest co-operation with Government specialists, and the most minute constant official inspection. Readers can appreciate the high standard set, and the difficulties involved, from the fact that, in spite of this vast effort, all the masks produced in 1917 were not allowed to be sent to the front, but were supplied to troops in the home training camps.

The increasing calls for masks, and the complexity of the organisation which was developing, coupled with the transport difficulties which were arising in different parts of the country, all pointed in the direction of a central gas defence plant. The decision was made in November 1917, and by the summer of 1918 one of the most unique industrial developments ever witnessed was achieved. Some twelve thousand employees served the plant at Long Island City, including more than eight thousand women, and in eight months this organisation was producing vast quantities of serviceable masks, July witnessing the production of more than six hundred thousand.

CARBON

Of all the features of this great enterprise, the development of the right kind of carbon was perhaps the most important, and certainly the most romantic. In principle, the soldier was protected from poison-gas by carbon, which absorbed it, allowing

pure air to pass on, and by the chemical granules which attacked it and resolved it into harmless products. The weight and design of the mask necessitated that this chemical defence should be exceedingly active, producing the desired results with the smallest possible weight and volume of material. The state of chemical and physical knowledge in 1917 pointed clearly to the use of carbon as the active absorbent. The classical researches by such investigators as Sir William Ramsay, and the use of absorbent carbon in many industries for gas purification, gaseous reactions, and similar purposes, left no doubt on that point. But, although carbon was the best material, it was not available in bulk in such an active form as the mask required ; so much so that it is fair to say that as a result of gas mask investigations new forms of highly active carbon have developed, which are now available for, and applied in, industry to an extent unknown before the war. Under the stimulus of a great need, the war compressed into a year or two the carbon developments which would undoubtedly have evolved under peace conditions, but would have taken from ten to twenty years.

The evolution of carbon in America for gas defence purposes is an industrial romance. As pointed out above, the first fundamental need was a very active form of charcoal. But a second equally important one was for a very dense product which compressed its high activity into a very small volume. This needs no explanation, since it is obvious that the gas mask was only part of the soldier's equipment, and, in addition to reducing the weight he had to carry, it was of the utmost importance that he should not be burdened with large, cumbersome appliances hampering his movements. In the laboratories of America, France, England, and, in fact, of all the belligerents, work went on incessantly to ascertain the ideal source of carbon to meet the above standards. From this it gradually emerged that certain forms of carbon made from nuts and other vegetable sources were superior to other known forms, and of these the coconut shell headed the list, because, although active and dense, it was superior in hardness, and did not therefore tend to crumble and clog the soldier's mask under severe movement.

An alarming fact soon emerged. The call for masks from the armies threatened to exceed the supplies of the raw material. At first, frantic efforts were made to find substitutes for the coconut shell, and almonds, acorns, grape-seeds, coco-bean shells, peanuts, oil shells, and a hundred other sources were

rapidly investigated and found wanting. The normal supply of coconut shell in America was based on the consumption of fresh coconuts, which was adequate to yield about fifty tons of shells daily. These coconuts were used mainly in conjunction with various sweetmeats and luxury foodstuffs, so that the war restrictions on the use of sugar made alarming reductions in coconut consumption. Out of this arose the " Eat more coconut " campaign, which found such a response that the availability of shells was more than doubled fairly soon. The American forces required about fifty tons a day of shells soon after their entry into the war, and, by the end, four hundred tons of shells were required daily. This quantity was far more than the total amount available from the two American continents, including tropical America. The great source of supply was the East, where, for example, Ceylon produced 2,300,000 nuts annually. British India, the Philippines and the Dutch East Indies were next in importance, the total from all Eastern sources being capable of yielding between three and four thousand tons of coconut shells every day. Although this was more than the world's war needs, yet the difficulties were great owing to transportation, which was economised to the maximum on account of the limited capacity and its reduction by the submarine campaign. Now it is a fact that the preliminary heating of coconut shells to make charcoal for active carbon reduces the weight down to one quarter of the original weight of the shells. It was therefore important to carry out this first step as near to the source of supply as possible, and a charcoal plant was erected for the purpose in the Philippine Islands, from which purchases were made in all parts of the East by agents, and to which, towards the end of the war, enormous supplies of shells were being shipped. In spite of these vast supplies, the colossal increase in the American forces reintroduced the need of substitutes for the coconut shell.

The first of these was the Cohune nut—smaller than the coconut, but with a thicker shell. This nut illustrates the difficulties which arise in quite unsuspected directions in armament development. It was found that the chemical nature of the nut and its acid content rotted the jute bags and caused spontaneous fires in the storage dumps. In spite of this, over one hundred tons a day were being imported from Central America at the end of the war. The ivory nuts normally used for button-making were also gradually coming into use. Finally, fruit stones were employed, particularly apricot and peach. The products, including walnut

shells, were available in astonishing quantities, about twenty-four thousand tons being produced annually from the Pacific coast canning industry, and a campaign arose to stimulate consumers to save these products.

Technically, of course, the actual manufacture of the active carbon was a far bigger problem than collecting the raw material. Quite apart from private enterprise, the American Government spent vast sums of money in charcoal activating plant. The carbon problem probably made a more direct appeal to the civil population than any other armament feature. In America innumerable posters were seen bearing the words "Help us to give him the best gas mask," and hundreds of thousands of pamphlets were distributed. The different States held gas mask days, rather on the lines of British flag days, for the purpose of collecting carbon material, and large numbers of similar examples testify to the extreme urgency of the matter.

I have gone into this subject at some length, because it shows very clearly, and particularly to non-technical readers, the great volume of lengthy co-ordinated effort involved in the development and production of large quantities of an important item of defensive armament. In this sense the gas mask is a good illustration of the fact that disarmament is real if it leaves the nations with this kind of work not yet completed, and mainly to be done at the outbreak of war, if they wish to embark on it in defiance of covenants. In another sense, however, it is a bad example, because the gas mask is probably the one feature of armament which should be developed to the utmost in the interests of disarmament. The argument is quite clear. Chemical disarmament must be more effective if means of defence are developed to such an extent that the chemical weapons at that time are ineffective. The bigger the gap between defence and aggression in favour of the former, then the less will be the incentive to make chemical war. As we increase the gap, so we reach checkmate, and the value of the chemical weapon diminishes.

CHEMICAL MUNITIONS

The facts and figures which I have assembled in connection with various types of normal and newer armament will come as a surprise to many. In a sense they constitute a challenge to people who have questioned the value of armament limitation. The claim that a peacefully disposed country, highly organised for

industry, with vast facilities for manufacture of all kinds, can suddenly spring from a condition of disarmament to one of intense armament appears to be untenable. It is imperative to discard the conception of lightning conversion of factories, and to substitute for it a more accurate view based on facts. But the argument has often been advanced that although a case might be made for normal armament limitation, the extremely rapid availability of chemical munitions weakens it almost to the point of futility. Here again facts are required, and fortunately they are available. Our subject compels, and chemistry readily admits, the subdivision of chemical armament into two classes: standard chemical munitions, themselves relatively new in armament history, and the new agencies of chemical war. These classes are almost exclusively composed of explosives and poison-gas respectively.

EXPLOSIVES

Of what order is the time factor in the expansion of explosives production? These products cover two essential groups, apart from raw materials, i.e. propellants and high explosives. The chief raw materials are cotton, toluol, phenol, caustic soda, sodium nitrate, sulphuric acid, nitric acid, and ammonia. They are all very important components of normal chemical and allied industries; there is no question or possibility of limiting them, which would be folly, and disarmament is concerned with later steps in the life of explosives.

Smokeless powder was one of the most widely used propellants. Its production in America was forwarded by the construction of two enormous factories—the Old Hickory plant at Nashville, Tennessee, and the Nitro plant, near Charlestown, Virginia. The former was probably the largest in the world, and was so self-contained that it covered every process from the raw cotton to the finished powder, including the manufacture of the acids and solvents required. This wonderful undertaking, pushed forward at lightning speed, gives us a fine example of production lag in explosives. The estimated cost was ninety million dollars, and negotiations in 1917 led to a contract with the Du Pont Engineering Company, whereby the latter were to construct the plant and operate it for a period of six months after completion. It is important to remember that the experience and resources of the Du Pont Company were such that probably no organisation in the world was better fitted to undertake this gigantic task.

The unit of manufacture was termed a powder line. Nine of these were planned, each to produce at least fifty tons of powder per day. The first was required to commence production in September 1918, nearly eight months after the signing of the contract. Actually, ground was broken early in March 1918, and the first unit was in operation early in July. Here, then, we see the erection of a new plant for the manufacture of a normal chemical munition, employing a known process, by an organisation possessing unique skill and unlimited backing and resources. Lightning speed meant, in fact, a delay of four months for the operation of one of nine large units. Another four months were necessary to carry the plant to ninety per cent. completion, and operating at about one-half of its planned capacity.

The factory at Nitro, although a typical example of high-speed development for normal chemical munitions, does not show such rapid progress. Ground was broken in February 1918 for a factory designed to produce thirty tons of propellant daily, and output had reached one-sixth of this maximum in nine months. When we remember that the Old Hickory and Nitro enterprises involved the construction of works for subsidiary processes such as the purification of cotton, the manufacture of sulphuric and nitric acids, of diphenylamine and other chemicals, and of houses, churches, schools, roads, and general facilities for many thousands of people, it seems to be a correct conclusion that the plant lag in normal chemical armament is considerably less than in mechanical armament. There is no case on record of the development of plant in such a short period as four months to produce enough guns to consume a fraction of the first four months' propellant output of Old Hickory.

Space forbids more discussion on the bearing of propellant manufacture upon disarmament. Actual manufacture is not all, for it must be followed by loading. Two methods are employed. For small arms and low calibre guns, the destructive shell itself is fixed to a metal container which holds the propellant powder. For higher calibres, the latter is loaded into silk bags, which are placed in the breech behind the projectile. It will be readily understood that mathematical accuracy and lightning speed are essential in propellant loading. The charge determines the range, and a slight deviation under the correct weight means death in the ranks of the gunners' own comrades. Yet great loading speed is required to keep up with shell production. The technical problems are of the same order as those of actual manufacture.

Loading demands essentially a large number of small mechanical units, operated by extremely careful personnel, maintaining regular output at high speed, never departing for a moment from the fixed standard. For operations on a colossal scale, one of the main difficulties is the assembling of an adequate number of reliable operatives. This cannot be done in a moment, and would always represent a substantial element of delay in the organisation of armament production for large-scale hostilities.

High explosives, the actual agents of destruction, are probably the best known forms of normal chemical armament. The well-known T.N.T., or tri-nitro-toluene, was produced on a large scale for commercial purposes before the war, for in America the figure reached three hundred tons per month, and before that country joined the Allies this figure was more than doubled. By the time of the Armistice it had multiplied by a factor of seventeen, reaching a monthly output of approximately eight thousand tons. The process of expansion was very largely one of building and operating new factories, and the rate of development of this production is well illustrated by the case of ammonium nitrate, which was used in admixture with T.N.T. to yield the well-known amatol. Late in 1917, American specialists studied the Brunner-Mond process in England, and, as a result, ground was broken in America early in March 1918, and manufacture was in full swing early in July. Here we have a lag of four months for one of the simpler components of normal chemical munitions.

THE NEW CHEMICAL AGENCIES

Poison-gas or chemical warfare is a matter which cuts deep into disarmament plans. It is the outstanding example of the coming new agencies of war, and its close interlocking with scientific development and the industries of peace is characteristic, and adds special problems in practical disarmament. We can learn a great deal by comparing American and German production. These new chemical munitions can be produced by the national chemical industries, particularly those sections which deal with synthetic organic chemicals. Broadly speaking, the pre-war American chemical industry, particularly on the latter side, was small, feeble, and undeveloped, while Germany possessed the most efficient, vast, and comprehensive chemical industry which the world had witnessed since chemicals became a commercial commodity. The development of war requirements of

poison-gas in these two countries, one so poorly and the other so superbly equipped for the effort, affords a striking comparison.

Chlorine was itself used as a poison-gas, but is even more important as one of the chief raw materials of many of the other more complex war chemicals. Isolated as a gas in certain chemical reactions by the chemist, Scheele, in 1774, it was identified as an element by French and English scientists, including the famous Davy in 1810, who gave it the name chlorine. Its first industrial application was to bleaching, which was suggested by the French chemist, Berthollet, as early as 1785. In four years it was on the market as Eau de Javel, produced by passing chlorine into a solution of potash. The high cost of this process led to the suggested use of lime instead of potash by Charles Tennant in 1798, which was actually translated into commercial practice by him at his St. Rollux works in the same year. But the gaseous chlorine of those days could not be seriously considered as a weapon, for its mode of production and physical state did not allow its easy conveyance to, and use, on a battlefield, nor had organic chemistry so far developed those noxious chemicals which required chlorine for their large-scale production. But when the possibility of industrial liquefaction of the gas came in sight, it then became a potential weapon and the mother of others. French, German, and English chemists contributed towards the early processes of liquefaction of chlorine, but it fell to that great German firm, the Badische Anilin und Soda-Fabrik, to be the pioneer of industrial production of liquid chlorine under pressure supplied in strong iron cylinders. This material was required for the manufacture of indigo, sulphur black, and other dyestuffs and organic chemicals, and provides a good example of my statement that the development of war potential to a point perilously near its climax is inherent in modern industrial development, quite independent of the form of government or of war-like intentions. The possibilities will arise in a pacifist or chauvinist State. No one would suggest that the early workers explored the properties of chlorine for military purposes, and the commercial importance of liquid chlorine was more than adequate stimulus for the German industrialists. The service they rendered to modern chemistry, and the great commercial prizes which they later reaped, quite eliminate the need of any military motive.

Thus, when the war broke out, liquid chlorine was being produced for industrial requirements at the rate of at least forty tons per day. This was a large quantity, even for military purposes,

for it meant that one day's output was sufficient to provide enough gas for a cloud attack upon a front of two thousand yards, and a week's output for a gas attack upon a gigantic scale. England, America, and France were lamentably situated in this matter, which, however, cannot be ascribed to their pacific intentions, but rather to the backward state of their chemical industries in general, due to that lack of research initiative which has since called forth volumes of self-reproach, largely as a result of the war. They possessed a negligible capacity for the production of liquid chlorine, and the manufacture of those chemicals for which it was required was practically a German monopoly, for England possessed only one firm manufacturing that product, on a very small scale, and the other Allies were scarcely better off. As a result, America took the characteristic bold decision to lay down two units at Edgewood Arsenal, each capable of producing fifty tons of liquid chlorine per day. Five months elapsed between breaking of ground and commencement of production.

As regards the availability of reasonable quantities of liquid chlorine, a well-equipped Germany was simply faced with an enforced reduction of industrial supplies, the diverting of the margin to war, and a rapid expansion of existing units. There may have been a few weeks' delay, but she would in any case have had a start of nearly six months as against a country possessing no peacetime production of the commodity, which provides a clear illustration in the difference of the war potential of two such countries in times of peace or at the outbreak of war. At this point, however, we must not forget that liquid chlorine available in bulk, or any chemical so available, does not provide a weapon. There are the further delays involved in the absolutely essential steps of the design, production, and testing of the projectile or container, and the other big problem of shell or bomb filling, which is dealt with later on. I must also point out, however, in order not to mislead the reader, that the excessively rapid availability of chlorine as a weapon in Germany was due to a fact which was, and will probably remain, exceptional. It so happened that the commercial commodity, chlorine, was itself capable of use in battle, but the more usual case is the one where the war chemical is several steps removed from the peacetime product, requiring further research and further plant development, and therefore further time for its manufacture.

Phosgene, probably the most deadly of the war gases, provides a parallel case. It is a vapour at ordinary temperatures, and was

discovered by Davy more than one hundred years ago, when he mixed chlorine with carbon monoxide, the deadly gas evolved from a charcoal fire, in the presence of sunlight. This method was entirely inadequate for industrial production, and at that time the product found no commercial use. The latter developed when phosgene became a necessary starting-point for the manufacture of certain very important dyestuffs, including the cotton scarlets so widely used in England, and by that time the essential chemical for the production of phosgene, liquid chlorine, had become a practical proposition. Thus again, in 1914, the situation was ripe in Germany, as in no other country, for the use of phosgene for war purposes. That country possessed manufacturing experience and a fair production, the increase in which depended only upon multiplication of known units of plant, while, outside Germany, production and experience were so slight as to necessitate a fresh start. In America, plants were established at Edgewood, Niagara Falls, and Bound Brook, N.J., which will afford a good idea of the lag involved. At Niagara, where a small experimental plant had been developed, nearly eight months were needed to yield an output of five tons a day; while at Bound Brook six months witnessed the realisation of the same daily output. Edgewood was the biggest enterprise, where an output of twenty tons a day was developed in nine months.

Some of the more complicated war chemicals such as mustard gas will well repay examination. It is not at all clear when the Germans first gave this product their earnest attention as a war chemical. If we could argue from our own experience, we would say that it must have been at some date earlier than the spring of 1916, because they employed it on a large scale in July 1917, and we took fifteen months to reach this position. They, however, were better equipped for the purpose, and the reasons have deep bearing on our subject.

Many years before the war the chemist Guthrie, as I explain later, made mustard gas by the action of sulphur chloride on ethylene, whereas Victor Meyer discovered another method by acting upon ethylene chlorhydrin with sodium sulphide, and changing the resultant product into mustard gas by the action of hydrochloric acid. Now, one of the great German chemical triumphs of the last half-century has been the manufacture of synthetic indigo, an achievement almost without parallel in the history of the application of science to industry. Several successful processes resulted from their work, and, when the war broke out,

one of these processes for which extensive plant existed involved the production of ethylene as a first step and of ethylene chlorhydrin as a second. These were the two most difficult steps in the manufacture of mustard gas by the Victor Meyer method. All that was required to complete the mustard gas scheme was the supply of two chemicals : first, sodium sulphide, which already existed on a large scale, this chemical being used very widely as a raw material in the dye industry, and, secondly, hydrochloric acid, which was equally well assured. Existing plant was found well suited to convert the intermediate products into the end-product, mustard gas. Thus, on the basis of proved processes, by the adaptation and multiplication of existing units, the problem of mustard gas manufacture was solved in Germany.

No such experience and plant existed outside her borders. When the need came, and the decision to use mustard gas was made, French, American, Italian, and British chemists speedily produced small quantities in their laboratories by the Victor Meyer method. The large-scale production, however, was another matter. It involved endless difficulties. In England, nine months of valuable time, and some hundreds of thousands of pounds, probably over a million, were spent in converting the laboratory process into successful large-scale production. Meantime a new process, on the lines of Guthrie's old investigations, was worked out in France and England, whose large-scale conversion proved more feasible and much more speedy. At the end of the war the Allies boasted that they were on the verge of swamping their enemies with mustard gas. This was literally true, but whatever the reasons, and they were many, the fact remains that fifteen valuable months elapsed after successful use of mustard gas by Germany before that boast could be made good. Only where experience and plant existed already in peacetime equipment was production free from this dangerous lag.

As a matter of fact, we must not exaggerate the speed of conversion for war production in a country possessing the maximum chemical war potential in that matter. Surveying all the fighting countries, one knows from experience that there were from twenty to thirty factories actively engaged in trying to produce mustard gas. Actual contact with many of these factories leaves no doubt that, even in cases where the chemical problems were quickly mastered, the dangerous nature of the material introduced substantial delays. One could point to various factories in the Rhone valley where, had mustard gas been a harmless commercial

commodity, it would have been available several months sooner than it actually was. All kinds of changes had to be made in plant design, which were related simply and solely to reducing casualties amongst the workers and specialists. For a country possessing relatively small initial advantages in this type of manufacture, France was extraordinarily successful with mustard gas, and it was from her that Germany received an unexpectedly quick and effective reply on the front. So confident were the Germans that manufacturing difficulties would cause Allied delays that they first reported that our use of mustard gas could only be from quantities collected from unexploded German shell collected on the battlefield, but the truth was that one particular French factory had been signally successful.

The Société Chimique des Usines du Rhône was a firm of high repute and well-developed technique in chemical manufacture. This company developed a new process on the lines of Guthrie's discovery. It was fundamentally different from the German process, and did not give them the advantage of bulk availability of the raw materials and intermediates, but it was mainly from their production that the French were able to reply, for the Allies, to the serious chemical threat of mustard gas. They, in conjunction with the French Government, developed a combined group of factories from which the mustard gas was dispatched as filled shell. It took from six to nine months to get substantial production of the gas itself, and from twelve to fifteen months before the whole unit, including shell filling, was in bulk running order. Every competent person associated with, or watching, this enterprise knew that it was a marvellous effort, and that it was extraordinarily doubtful whether any chemical company, including those of Germany, could have moved with greater speed from the same beginnings.

In the present state of industry it would be true to say that poison-gas supplies for war involve a shorter production lag than many other forms of armament, but our short summary shows it to be equally true that there is a definite and substantial lag, with no question of sudden conversion to the manufacture of bulk supplies. As a matter of fact, the industrial chemist knows on reflection that this is so, although he may not have viewed his industry from this angle. All those who manufacture and sell industrial chemicals will frequently have been faced with the possibility of large promising orders for some chemical out of their range, but only slightly different in composition and technique

from their existing products. It may be, for example, that a dye-stuffs intermediate slightly changed would find wide consumption as an insecticide or wood preservative. In such a case the most careful attention has to be given to delivery dates, giving the necessary number of weeks or months to make the slight adjustments in plant, add a new unit for the last operation, ensure availability of any new raw material, arrange for special containers, and a host of points which vary from case to case, and which make the time factor the main consideration. There is no question of sudden conversion, but a definite lag which often becomes the governing factor in obtaining the order, and which runs into many months if really large quantities are involved. To show that we must not exaggerate the speed of conversion or of new production for war chemicals it should be mentioned that there are some industries which have a very much shorter lag. For instance, in the rubber industry the change over in bulk production from one composition to another is often exceedingly speedy. The manufacture of a composition, say, for a hose to resist petrol, can be switched over to one for conveying acids within a few hours, provided the necessary knowledge is available. The machines are highly standardised, and it may only be a question of changing some of the ingredients of the rubber dough or mix, and of adding or removing a few minutes from the time of vulcanisation in the same press or vulcaniser. Had it happened by some coincidence that rubber compositions might be devised suitable for producing casualties, had simple derivatives of the rubber molecule possessed lethal properties able to be used in war, then this would have presented a special problem in disarmament, inasmuch as the conversion lag would have been perilously near the "overnight conversion" which has been an unnecessary bogy in the field of disarmament.

But in the new agencies of war the production of the chemical is not the whole story, either for armament or disarmament. A nation might have a reserve of a million tons of the most potent poison-gases in storage tanks and yet be many months removed from their military use. I deal with this subject later from another point of view, but must make brief reference at this point. Just as the projector is useless without the actual casualty producer—the shell or bullet—so the war chemical depends for its life as a weapon upon the projector and upon its container. Where poison-gas is used in shell by artillery, the production of the gun and of the shell also become governing and limiting factors, and we get the

interlocking effect of different elements of armament by which any disarmament scheme must partly be judged. But there is also a new and special problem with poison-gas, which is the question of special containers and of shell or container filling.

There were, of course, some cases in the history of the new war chemicals in which unusually high speed of conversion was attained, and they corresponded in principle with the special case of a process similar in all but the last stage to that of the manufacture of a peacetime chemical, the end-point being reached in the same type of operation, but using different reacting substances. For example, one of the features which most impressed the Allied Commissions to the Rhine factories at the end of the war was the great ease with which they had adjusted to manufacture the organic arsenic compounds, substances which were being developed by Germany in Blue Cross shell, having some vesicant or skin-attacking powers combined with other effects, such as lachrymation, and curious mental states which we describe elsewhere. They were important, not so much on account of the actual results attained, but in view of other, much more potent, similar bodies towards which they were evolving. In this case the German factories had employed their standard azo-dyestuffs plant to perform the necessary reactions, and it is extremely likely that the change-over occurred in a few weeks, but in my opinion such an exception cannot be regarded as having damaging bearing on the general case for disarmament.

For instance, it might be said that if a new gas of supreme importance as a casualty producer came forward, and if it happened to be similar in production characteristics to the above example, it would go far to neutralise the value of the long conversion periods associated with other forms of armament. We must remember that, for this to be the case, it would mean that this particular product became the backbone of the chemical war, replacing a number of others, each produced in moderate tonnages to give the necessary formidable total, and it would by itself have to reach that order of quantity. That being so, the production characteristics would change. An azo shed, for example, able to produce sufficient war chemical to satisfy the needs of one relatively unimportant member of the war chemical range would no longer be sufficient, and the old problem would again be introduced of building up a new industry from rock bottom. This question of chemical production, and, in fact, of all technical production, is very specific, and, for any single weapon or item

of armament, conversion is not applicable to the huge plant facilities of a whole industry, only one relevant section of an industry being of use. For instance, when we thought of the might of the German I.G. supporting a chemical campaign in which the chemical type was a complex organic, it was misleading to visualise their vast resources of synthetic nitrogen plant making any material contribution to direct production. That high-pressure gas and catalytic plant had no more bearing upon a complex organic arsenic derivative than had a motor-car factory. In the case of a new chemical of such importance as to introduce the possibility of military results, the quantities involved at once begin to subject it to the production delays of works and plant organisation common to all forms of modern production, and turn a period of weeks into months, or months into years.

Again, and broadly, the same comments apply as were made at the conclusion of the last chapter. We must, in order to be accurate in our generalisations, obtain an individual view of the production characteristics of the separate items, but a general conclusion is only permissible in terms of the whole evidence. Is such a conclusion essentially different in the case of the new agencies of war as in that of normal armament? The position very briefly is as follows. Where the new agencies involve the same type of industry, machines, and general organisation as normal armament, then our conclusions are valid, but where they enter new sources of production, such as chemicals from the chemical industry, they will be governed by the characteristics of that industry. It is a fact that in the chemical case the conversion lag is in general somewhat shorter than for normal armament, but only in very rare cases is it so short as to affect the argument.

As we have said before, a chemical is not a weapon, and a nation could have enormous quantities in stock without being much nearer to successful use in war. There is the same interlocking of a series of stages in the life of the weapon as there is for normal armament. The total lag of the chemical weapon must take note of production of the container, the filling problem, and all other complementary essentials. It is true that relatively simple forms of container may come forward in chemical warfare, but, if so, they will be new forms, and any relative ease of production to which they might be subject would tend to be neutralised by their novelty, and all the difficulties of production which usually attach to an entirely new feature of industry, however simple it may be.

Then, again, we must remember that so far the technique of war is such that the chief new agency, the war chemical, is very largely employed in shell, and such use would therefore be governed by all the factors which relate to the manufacture of guns and shell. There is, of course, the very special combination of gas and aircraft, and this is probably the one field in which the somewhat shorter conversion lag for war chemicals could have special bearing on disarmament and special danger in a disarmament scheme.

A fair conclusion would be that, taking everything into consideration, we have no reason to believe that the new agencies of war have such production characteristics that they remove from a disarmament scheme any security which the delays involved in normal armament would give it.

No one can forecast what will occur in the future, as science and its industrial applications progress, but the longer view we take the more we have to consider the possibility of some form of armament coming forward, which, through its production characteristics, neutralises the value of production limitation in disarmament, and, the more weight we attach to such a possibility, so we must begin to consider practical measures of controlling the evolution of new types.

This is an aspect of disarmament which is to-day practically untouched, and which I think is indissolubly associated with disarmament in quantity in any rational scheme, and it is dealt with later on. The broad conclusion is that in the present state of armament the time characteristics of its production render quantity limitation a feasible and valuable disarmament measure, but that if we leave the question of type unattended to, and simply assume by argument from the past, but against all the indications of the future, that nations will not develop disparity in type, then this valuable adjunct in disarmament may simply become a source of danger.

CHAPTER VI

ESSENTIAL PRINCIPLES OF DISARMAMENT

General Considerations : Quantity and Type : The Time Factor : The Possibility of Effective Disarmament : Total Disarmament : The Safety Level : The Danger Level

GENERAL CONSIDERATIONS

The subject of technical disarmament is closely associated with the study of armament. A complete investigation of the latter being impracticable, the last two chapters have exposed certain armament facts, chosen for their special bearing on disarmament. These mainly relate to expansion, but they also touch on arms development, and the necessary background of evidence for this aspect of the subject is consolidated in a later chapter when dealing with the new agencies of war. We now approach the question of a rational disarmament framework, general principles, reasoned standards on which practical proposals can be based, or against which they can be measured. In other words, we prepare to examine applied disarmament.

The latter brings in all kinds of interesting questions. What is the position of the private armament industry ? What forms of armament should be limited and controlled ? May other forms be left unrestricted ? But these questions, and many others which we shall discuss, must be left for the moment, until we have dealt with certain broader matters of principle upon which the answers will largely depend.

It will be seen in the chapters which follow that constructive measures do actually emerge from this type of treatment, and they may appear so sound in theory and so desirable that I hasten to remove any suggestion of urging blind adherence as the only means of practical progress. Many measures which have been, or may be, proposed officially, may well partially deny some rational conclusion which our treatment may establish, but it might be in the highest degree harmful to discredit or renounce them for this reason alone. We fully know that the structure of

any programme before it is adopted and operated will be distorted under the stress of compromise arising from political, economic, and moral forces. Faced with a programme of maximum technical validity, one nation will find that it must ask for concessions, and another may be generous enough to grant them. But each will at least realise the extent of their departure from the position of maximum security. It is of the utmost importance to frame a rational programme before we proceed to saddle it, if we must, with the errors of the past, the greed of the present, and the fears of the future.

The subject of applied disarmament admits logical treatment in two main classes : normal armament and the new agencies of war. But before proceeding to examine the special aspects of the former it would be wise to draw attention to an underlying problem which seems to crop up, usually unrecognised, in official disarmament schemes and proposals, and which frequently arises in the chapters which follow.

QUANTITY AND TYPE

This is the problem of quantity and type. The idea is very simple, but to ignore it leads to endless confusion, not only in the academic discussion of disarmament, but also in practical issues arising in the international field. Various proposals for technical disarmament brought forward up to the present involve agreement amongst the nations concerned whereby they would reduce the quantity of the different forms of armament possessed by each, in accordance with certain ratios and below certain totals. This method is referred to officially as direct limitation, contrasted with indirect limitation, in which quantity possessed is controlled by armament finance in the national budget. It would not be true to say that every serious official discussion has favoured direct limitation, for even to-day, at the meeting of the Preparatory Commission for the Disarmament Conference, direct limitation has been vigorously opposed by a number of countries. I refer later to the logical aspects of budgetary limitation, and it is clear beyond any shadow of doubt that this method alone is but a first small step towards disarmament, which still allows the nations to work for and possess that disparity in armament which it is the first objective of disarmament to prevent.

I do not mean that one should not accept the budget method if it is utterly impossible to go a step further at the time in

question, but to regard it as a final system of disarmament under which the world can rest with fair assurance of security and peace is a fallacy so open and obvious that it is incredible that twelve years of disarmament negotiation backed by adequate investigation should find us in danger of having to accept the budget method. In any case, whether under direct or budgetary limitation, the problem of type is of acute importance. The object assumed in direct limitation, even if not always stated, is a condition of much more stable equilibrium, introducing physical obstacles against the outbreak of great wars, removing critical and decisive armament advantages as between one nation and another, and thereby preventing a quick, successful, surprise attack through outlawed aggression. It is assumed that a more stable equilibrium can be and would be attained, and there can be little doubt that this is a real possibility. But the assumption that proper distribution of armament quantity can lead to such a happy state of affairs can only hold good in reason if another assumption is made, and rigidly acted upon in practical disarmament issues. This second assumption is the equivalence of the armament type to which the limited quantities relate.

If there is to be real stability through quantity, it means that this must be defined in terms of certain units. For instance, consider a scheme dealing with quantity of infantry. Although the scheme is outwardly based on numbers of combatants, it is the magnitude of their effective action which is really implied or tacitly assumed. The number of men is only a real guide so long as each is capable of approximately the same casualty production, which means that the individual weapon, say the rifle, must be of the same type. It would be futile to adopt number of men as a guiding factor, and to find one nation with a rifle five times as effective as that of another through improved mechanism or design. It would be useless from the disarmament point of view to have nations going into such schemes with the mental reservation that their equality or other agreed relationship in arms can be altered, without going outside the letter of the law, by displaying great secret ingenuity in improving the type of weapon. Or, again, in the matter of naval armament, we have the classical contest between the advocates of global tonnage and disarmament by categories. The former implies a wide freedom as to type of naval armament within a tonnage limit, whereas the latter begins to approach the sound disarmament principle, with quantities based on a common conception of type.

We can see that this is an intensely practical matter by visualising the position which might have occurred if the world had been seriously considering or operating a disarmament scheme at any time in the recent past, when some positive step forward in arms evolution took place. Thus, for example, about 1880 the infantry weapon was the rifle. There were some machine-guns, but their effect was negligible compared with what occurred later. It was true at that time that infantry strength in a disarmament scheme was reasonably measurable, and under agreed and well-thought-out systems of reduction a valuable equilibrium towards peace could have been maintained. Then, as we have seen, quite suddenly, almost out of the blue, came the Maxim gun. Within a year or two it was a perfect weapon, able to be produced in large quantities. The question stares us in the face as to what would have been the value of that equilibrium if any one nation had quickly acquired a large number of this weapon. Let us assume that we had acquired it, and compare the fighting efficiency of, say, a German or French battalion with no Maxim gun and a British with an equipment of even ten. The equilibrium would at once have become false, and the disarmament scheme unsound.

It is incidental to the argument and the future that at that time the world's organisation of armament production, or lack of it, was such that this weapon was offered to, and made available for, all countries indiscriminately. But it is very much to the point that even to-day we are far removed from this casual distribution of improved armament, secrets, and appliances, and are moving more and more towards national retention of armament progress.

Or, again, consider what the situation would have been if the Great War had not occurred, and the nations had evolved and submitted to a scheme of armament reduction and equilibrium in quantity, while at the same time one of its members had developed the chemical weapon by some combination of circumstances similar to those which produced the Maxim. The possession of phosgene, mustard gas, lachrymators, not to speak of more advanced chemicals, with some elementary technique for their employment as weapons on the field of battle by one nation, the others being in ignorance of the development, would have meant a situation far more unstable than ever occurred at any time through chemical warfare during the war. We would have had one nation chemically equipped, not only for aggression, but

for protection, and the others equipped for neither. The combination of moral effect and huge casualties on an unprotected army in the field would have been decisive. We could take other examples, and assume, say, that the Krupp evolution of modern artillery had not assumed an international character, but had been carried on within closed national walls, while other nations adhered stolidly to the old pre-Krupp artillery types. Or we could assume that the submarine had been seized by some nation as soon as it emerged as a crude weapon, and actively developed secretly.

These examples, and others we could mention, show conclusively that had history been readjusted a little as regards a few years of time, with disarmament schemes thrown back a few decades, the question of type would have arisen acutely, and there is no reason whatsoever up to the present to conclude that it will not arise again. On the contrary, I think we must assume that the new tendency towards secret development, and the great impetus which the war gave to the co-operation of science and armament, will increase this danger in the future.

To the best of my knowledge this question of type has never been faced as a specific and important problem in disarmament conferences. Examples of it have arisen now and again, as in the case of the Ersätz Preüssen, the submarine, poison-gas, and they have been grave obstacles, and still are, in reaching schemes for the limitation of quantity. But the treatment seems to have been to regard them as exceptions requiring special and difficult treatment, instead of appreciating that they represent a general problem just as much as, if not more than, that of quantity. Reading the official records, and trying to fathom the mentality and the intellectual line of approach of the experts and negotiators, it is difficult to avoid the following conclusion. There has been a tacit assumption that quantity ratios and limitation form part of the sound principles of disarmament, as indeed they do, and agreement on this point has presented no difficulty and wasted no time, although of course the practical application of this principle, and the compromise it involves, may be matters of long negotiation. But, with regard to type, there has been no general recognition of a broad problem, on which agreement already existed, or which required it. Indeed, the tacit assumption in this case seems to have been that the type question took care of itself, presumably because in many cases equivalence already existed. In other words, in agreeing ratios of combatants there

was no need to discuss the national forms of rifle which they would use, or, in agreeing gun quantities, matters were so standardised that a reference to calibre was sufficient, and so on.

Now it is a curious fact in the past history of armament that before the Great War national armament types were more or less equivalent, and it was quantity which varied so grossly. But disarmament is concerned with the future, and it cannot rest on conclusions drawn from the past unless the processes in question retain all their old characteristics in future development and govern it. If we can make this assumption, then considerations of type assume academic interest, but, if we cannot, they become vital. It will be seen at many points in the chapters which follow that the assumption is false, and that to assume parallel national progress in armament type, either by failure to recognise the problem at all or by conscious reliance on the past, would be fatal. I will not at this point examine the new policy and characteristics of the process of armament evolution, but it would be well to refer to the reasons why in the past so little disparity existed between nations regarding armament type, and why a factor with such great possibilities for decisive surprise in war was not exploited, and was subordinated to quantity.

The reasons at once become clear when we examine the process of armament development and the characteristics of the agencies which fostered it. The major part of pre-war production and investigation was in the hands of private and commercial organisations. They had the same freedom as exists in the exploitation of any commercial commodity ; the whole world was their market, and profit their motive. Governments did not greedily seize new armament features before competitors could gain substantial access to them ; on the contrary, they were extremely backward in taking advantage of the new types, and only did so under considerable pressure, often with a delay of several or many years, long after every other nation had had an equal chance to acquire and to study the weapon concerned. One has only to follow in detail the history of heavy armament, say through Krupp, of the machine-gun, particularly the case of Maxim, and of the submarine, for which official support, even in the great naval countries, was extremely lethargic, to appreciate the truth of the above generalisations, and to realise that armament exploitation was even more subject to international disclosure than many purely commercial products. But, as will be seen, a great change has occurred in this respect, and we can no longer rely entirely,

or even largely, upon the safeguard and levelling up process of the international trade in arms, and we arrive at the conclusion that the effective unit or standard for disarmament is not only quantity, but the latter related to a definite common or equivalent type, and if this is ignored the value of quantity disarmament will prove to be seriously prejudiced.

The question of agreement on type for known armament subjected to quantity limitation does not dispose of the matter. There is the problem of entirely new types of weapons, or of those so far removed from past weapons as to be outside the scope of a disarmament treaty dealing with known armament. Is it wise to leave these to the mercy of chance? The modern acceleration of scientific and industrial progress and its increasing facility to foster armament is sufficient, on broad grounds, without going into detail, to make new armament types of vital practical importance to disarmament. There were periods in the history of the world when the intervals between the arrival of new weapons or major improvements were so long that at such times, had disarmament been considered or in operation, it might have been pardonable to ignore the problem of type, and to treat it as only of theoretical interest. But an examination of the history of armament will show that for at least a hundred years this view could not have been taken, that during the last fifty it would have been positively dangerous, and that to adopt it since the war, and now, would be fatal. On such grounds as the above, reinforced by the many relevant facts exposed in the chapters which follow, it appears that disarmament schemes can only approach practical and maximum value as they begin to take note of the problem of type as well as of quantity. With this ever in mind, we can begin to probe the problems of disarmament in normal armament.

THE TIME FACTOR

The idea most aptly expressed, but somewhat exaggerated, in the term "overnight conversion of industry," has frequently appeared, and it is critical for disarmament. The astounding feats performed by certain industries during the war in the transition from their normal operations to the manufacture of armament are probably responsible for a suggestion which has repeatedly come forward with apparent authority. This transition, it is claimed, occurs so swiftly and silently as to be a real danger

to the organisation of peace. Swift and silent are relative terms, and it is possible for an industry in adapting to armament production to be moving with excessive speed, when measured against the standards of re-organisation and production in times of peace and yet at the same time so slowly as to prejudice the results of a campaign, and neutralise, if not entirely destroy, the surprise value of a new weapon. An effective sprint in industrial development for commerce may prove a harmless crawl applied to the organisation of supplies for a great war. It is easy to see how the misconception arises. Superhuman efforts have perhaps been made by an industry to turn out colossal quantities of some form of armament. Great ingenuity on the technical side, and amazing sacrifices and endurance by the workers, produce results which in peacetime could not have been conceived possible. The idea of incredible speed and unlimited powers of conversion spreads with cumulative effect. As a generalisation, as a measure of industrial achievement against industrial standards, it is correct, but in its bearing on a campaign, or in particular on surprise value at the start of a great war, and therefore on disarmament, we must ignore the general, and come down to facts. Was the development or transition a matter of days, months, or years? We do not have to look far afield—no farther, in fact, than the Teeside—to see an enterprise which has grown to vast production of an important commodity with incredible speed since the war. The best judges can fairly talk of speed in this case, and yet several years had elapsed, not days or weeks, since the new industry left the research or embryonic stage. I refer to the works producing synthetic ammonia, where huge tonnages of the new fertiliser, ammonium sulphate, are being produced from atmospheric nitrogen. The Germans were pioneers in this matter, and the time they took to reach bulk production was well known to be a matter of years. Even during the war many months were required to multiply their output in a new works, in spite of the facts that they already had manufacturing experience and were under a unique stimulus, for, as we have already seen, apart from this source their explosives supply would have failed.

The everyday happenings of any industrial country provide a mass of evidence to which hundreds of thousands of non-technical people have direct access, and in which they have a keen and very personal interest. I refer, of course, to public investments in new manufacturing companies, of which some thousands of cases have arisen in England since the war. New companies have

been floated for the production of artificial silk, Portland cement bricks, safety glass, motor-cars, and almost daily one has seen the prospectus of new manufacturing companies. To the shareholder the important question is, How soon can their subscriptions produce dividends? To the staff of their new company this means, How soon can the new works reach standard bulk manufacture? and most of us have had a vital interest in this question, as shareholders, employees, or promoters. We know that in any substantial manufacturing enterprise the period is never a day or a week or a month, but sometimes six months, and more often a year, with plenty of examples of longer periods. Now these are essentially cases with substantial facilities, great inducement, and very often much initial preparation by investigators. They represent valuable evidence relevant to the closely allied problem of time lag in armament production for war.

Therefore, in this matter of armament production, we must come down to facts and figures, and those provided in the previous chapters are enlightening. They deal with important armament features, the absolute backbone of war equipment, and include many cases of exceptional speed. What do they reveal?

The different types of armament show wide variations as regards the time lag involved between the decision to produce large quantities and their availability for war. The times also vary according as to whether investigation and research had to precede production, or, if this was unnecessary, whether new factories had to be built, or, if these existed, whether their personnel and capacity were adequate. For some types of heavy armament it was a matter of years, whereas at the other end of the scale certain chemicals and small arms accessories required only a few months. Thinking in terms of quantities sufficiently big to equip a substantial part of an army of any one of the Great Powers during the war, there is hardly a case over the whole range of armament where adequate deliveries were forthcoming in less than nine months, the average, if we can conceive of averages in matters of this sort, being from fifteen to eighteen months. Review for a moment the conditions to which these figures apply. We have a background of great industrial countries, all of them possessing considerable armament experience, none of them having been governed by any conscious and substantial disarmament policy, nor hampered thereby, and some of them, on the contrary, having carried armament investigation and production to a highly developed state in the great armament race prior to 1914.

Even in the country which was probably the least prepared, the United States of America, the conditions could be considered as extremely favourable to armament development, for her research, engineering, and manufacturing experience and facilities were practically unique in all directions. We must not forget, also, in this case, that, owing to the fact of her neutrality for some thirty months, America gained a vast amount of armament experience and productive capacity in fulfilling huge contracts for Allied countries.

In a matter of this importance, one would naturally be glad to supplement one's own observations with those of other competent observers. It is therefore unfortunate that not only have the discussions on this important question of time lag in armament production been few and far between, but, when they have occurred, they have been more of the nature of expressions of opinion, without reference to a solid background of facts. However, it will be interesting to refer to one such series of opinions expressed by Professor Baker in his recent book.[1] Discussing the limitation of potential armament production, he advances opinions as to the bearing of the speed of typical armament operations upon the efficiency of limitation. His conclusions are as follows : " . . . For the production of tanks and guns, and so on, a long period is required, and therefore Period A is of much greater duration than in respect of other factors of military strength. Supplies of poison-gas and aircraft can be quickly multiplied ; artillery and tanks cannot, even if machinery for their production is in existence. For guns, the time before they could be brought into action in any numbers could hardly be less than nine months, however efficient were the preparatory arrangements that were made. For tanks, the period would be even longer. Even for shells, to the production of which the peacetime machinery of engineering shops could be applied, the time required before they were delivered in the field would probably be at least from six to nine months. At the time when the production of munitions in Great Britain was most efficient—in 1917 and 1918—nine months on the average elapsed before shells ordered by the War Office were ready for use in France. It is forgotten sometimes how long the processes of shell production —casting, machining, filling, resting, inserting fuses, general assembly, transport here and there—must inevitably take. The period could in special cases have been reduced, but only by

[1]*Disarmament*, by Professor P. J. Noel Baker (1926), p. 314.

delaying the delivery of other kinds of armament and supply. It is, in fact, a complete illusion to think that an engineering industry can be magically transformed into an immense munition plant, producing in a few days or weeks finished products ready for the field. This cannot happen even if the necessary specialised machinery exists ; if it, too, has first to be produced, the inevitable delay becomes, of course, much longer."

These considerations, coupled with the facts which I have assembled in the previous chapter, allow us to make certain generalisations with a very fair degree of safety. For a country to be ready to spring into a first-class war with another Great Power and employ anything like its maximum war effort in the early stages, so far as standard armament is concerned, it must have been consciously organising for the event for a very long time. The actual time will vary from country to country, and depends on a great variety of conditions, chief among which will be its normal industrial equipment, and its policy in so far as it governs armament finance in and out of the budget, but in my opinion, for a country starting in a state of relative disarmament, the period in question is one of years rather than months.

Those of us who had the opportunity of seeing at first hand the results of conversion lag in armament production reflected in the events at the front will probably be fully convinced that the above conclusions are faithful to the facts. The few who were privileged to study both ends of the process should need still less convincing. It is interesting, however, to move from individual experience on to the broader grounds of the views of the great commanders whose policy and decisions would be intimately associated with, and often governed by, the time factors in armament supply. The best memoirs of such great leaders as Ludendorff and Haig fully bear out our conclusions, and we quote below from General Charteris's able book *Field-Marshal Earl Haig*.

He explains how Haig was fully alive to the vital importance of armament supplies, and the surprise use of new types in adequate quantity. The relative bearing and importance of German and British armament potential is well illustrated by comments on the Battle of the Aisne, when the line began to consolidate, open warfare was diminishing, trench warfare appearing, and munition supplies becoming decisive. He says, " The Germans' superiority in artillery (which influenced the whole trend of the fighting during 1914–15) now became evident. There was a continuous rain of well-directed and effective high-explosives upon the British

trenches, and the British had little high-explosive armament with which to retaliate, and that little was not giving good results" ; and later, referring to the Battle of Ypres in October and November 1914, "Even more serious than the loss of men were deficiencies in artillery and ammunition ; there were only one hundred and fifty rounds per gun in the theatre of war, and only seven rounds per gun were arriving from home." Referring to the great disparity in men, he says, "More important still, the Germans were able to mass two hundred and fifty heavy guns against the twenty-six heavy guns which was the total number that the British could muster." "There was no ammunition for the few guns he had available. Rather than keep the guns suffering hostile fire, which they could not return, Haig sent back a considerable portion of his artillery to rest outside the shell-swept area, handing over the small quantity of ammunition to the few batteries retained. Even with this supplement, the guns which now remained to face the concentrated fire of two hundred and fifty enemy guns could only be allotted twenty rounds a day for the 18-pounders and ten rounds a day for the howitzers."

Still more interesting are the comments throwing light on the lag in production after the British had taken munitions production in hand by forming a separate organisation in the summer of 1915. "Haig spared no effort to assist them to a knowledge of their task. No immediate results could be anticipated from any action, however energetic. It would take many months before orders given now could produce any acceleration in the supply to the field armies, and Haig explained to the visiting members the vital necessity of a careful watch being kept on any modifications which the progress of the war might necessitate, and the importance of making immediate arrangements for the supply of each innovation as it became known." "In his dispatches Haig points out that in actual fact the effect of the activities of the new system were not felt in France until after the Somme battle at the end of 1916. Before that date the army was still fighting with the ammunition ordered by the War Office under Lord Kitchener's administration." Even during the Battle of the Somme "there were many uncertain factors ; guns and ammunition were still not available in sufficient quantities according to comparison with previous battles, although the discrepancy was balanced to some extent by utilising French artillery."

Infrequent as these references to the armament situation and its bearing on the campaign may be, it is curious how they entirely

bear out our conclusions. It seems clear, however, that if, as appears to be the case, the history of the war so far written subordinates the importance of armament, and deals almost entirely with combatants, strategy, and tactics, it is not because the military staffs were not alive to the armament question, but because in the later organisation and administration the purely military side and armament supply became divorced. However necessary this may be in carrying on a great war, it would be a fatal viewpoint in considering disarmament.

Moving from normal armament to the new agencies of war, we have to consider a new factor in the theory of disarmament. The sub-division of the time lag becomes important for a special and serious reason. With normal armament we are entitled to assume, in general, that the early work of small and large scale investigation has been done. For instance, although continual improvements are being introduced into the machine-gun, and production will always be faced with some changes of design, yet the greater part of that work—the initial principle, the main features of design, the mechanical contrivances for the production of each part—have been worked out in long years of patient effort ; they are a present from the past. The time they represent in the armament production lag has been reduced to the minimum ; but with the new agencies of war this element of time becomes all-important. I deal later with this analysis of time lag, and at this point need only state that for new weapons and means of offence which have to pass through all the various steps of small and large scale research the period is certainly a matter of years. For instance, poison-gas was developed with high intensity by some of the Great Powers, beginning, roughly, early in 1915, but it was certainly not before the spring of 1917 that the weapon was available in sufficient variety and quantity to be regarded as a possible deciding factor in the campaign, and to be graded with the standard weapons, such as artillery, in importance. It is true that the first use of cloud gas attack by the Germans at Ypres in April 1915 on a relatively small scale might have produced a decisive surprise, but the combination of conditions was exceptional. Relatively speaking, the long line of the Allies had barely consolidated past the breaking strain, and we can hardly argue on broad lines from the hazard of that one attack. On the contrary, the one conclusion which could be drawn from the Great War would be that the surprise use for the first time of a potent new weapon on a small scale is not enough. After all, the first use of

chlorine cloud by Germany and that of tanks by ourselves only support this conclusion.

As a new weapon increases in military value, so it enforces upon the great military staffs the need of changes in administration and organisation to cope with its demands. The Tank Corps and the Royal Air Force provide such clear examples as to make it unnecessary to offer further explanations in this respect. Judged by this standard, poison-gas or chemical warfare has not yet taken its place as a rival of the traditional methods of offence. But this is very largely due to its scientific origin and nature, which make it so foreign to traditional military training and thinking, out of which have arisen the staffs and war advisers. Therefore I do not think it is fair to claim a longer period than two years, but rather would be governed by the facts that in the spring of 1917 poison-gas reached the position which, defined in terms of variety of types, manufacturing facilities, and staff opinions, placed it potentially, and in some cases practically, on a level of importance with the chief agencies of war. By variety I refer to its availability as mustard gas for shell, as phosgene and other types for use in the Livens projector, and as lachrymators and irritants, being used in large and increasing quantities as normal supplies to the artillery. Secondly, if we interpret policy and staff opinion in terms of approved programmes of production, and money allocated to their support, we can claim that it was certainly not earlier than the spring of 1917 that poison-gas was admitted to the group of major weapons.

This is a clear example in support of my conclusion that the development of these newer agencies under the most intense conditions involves periods to be measured in years. Of course, it would be possible to bring forward isolated cases in which the development of some new armament feature involved considerably shorter periods of time, but I cannot too strongly emphasise that generalisations of this sort must be framed upon, and viewed in, the light of a representative volume of evidence, and if any striking exception arises, as must be expected from time to time, its bearing on the argument must be judged by its intrinsic capacity to neutralise, by itself, any disarmament schemes in question. A general weakness in the latter would only appear if it were found that the volume of evidence, some of which I have assembled, is not sufficiently large nor representative. Certain important questions therefore arise which must figure largely in the minds of both advocates and opponents of disarmament, and

it now seems possible to venture an answer which is removed to a very large extent from the region of individual opinion.

THE POSSIBILITY OF EFFECTIVE DISARMAMENT

Is it possible, technically, to create a condition of effective disarmament? We know it is possible, obviously, to deprive ourselves of arms and the means of making them, but, unless such action has substantial effect on the prevention of war, it is not disarmament in the fullest sense, and its bearing will be mainly limited to national expenditure on arms. Can such a step to a greater or lesser degree have serious incidence on the outbreak or the prevention of a great war? Can it create a situation which would ensure to arbitration and the forces behind it years or months instead of weeks or days to come into play? Would it so hamper the striking powers of a great nation as to make it impossible to impose its will upon another in a short, sharp campaign, regardless of a world peace policy and world opinion? Instead of Titans surprising the world by leaping to an instantaneous struggle engaging all their forces, could we reduce them to the state of weaklings feebly striving for mastery, easily parted, and with no chance of early success? In other words, can disarmament carried to the necessary stage make it a practical physical impossibility, or in any case render it exceedingly difficult for nations to rush at each other on the colossal scale of 1914?

This question is really fundamental to disarmament. The answer to it decides very largely, although not entirely, whether disarmament is worth while. If we consider the position of a great body of national representatives and experts brought together to consider disarmament, such as the League of Nations in action at Geneva, and if we view them as considering their problem from first principles, it is difficult to see how they can proceed rationally without making this one of their first subjects of systematic examination. If my question were asked of any such body, the answer would be in the affirmative; it would be said that quite clearly it is possible to conceive, and, given agreement, to operate armament limitation to such a point that it becomes a very valuable means of preventing the outbreak of great wars. But if reasons were sought justifying this conclusion, they might be difficult to find.

It is therefore very important that the evidence relating to

armament up to date does emphatically support this conclusion. The lag in production is such that under conditions of adequate limitation of armament which deal with the means of manufacture a situation could unquestionably be created rendering it extremely difficult, if not impossible, for any nation to impose its will upon another by outlawed hostilities, in the face of other international methods of peaceful settlement and sanction.

If there is any doubt on this point in expert and well-informed quarters, I sincerely hope that this book will result in a thorough ventilation of the whole matter, accompanied by the exposure of all the facts upon which these doubts are based. But as an unbiased observer, having honestly collected and examined all the evidence within my power, I must take the most definite stand that disarmament carried to the necessary stage, and operated without undue departure from its logical requirements, can render it exceedingly difficult to repeat the unhappy and disastrous developments of 1914, and eventually make great wars a practical physical impossibility.

TOTAL DISARMAMENT

The highest state of disarmament is one of no armament, or one of complete permanent moral disarmament. A world absolutely disarmed through the operation of moral and spiritual forces requires to my mind a state of perfection which will not be a practical condition of humanity until a very distant future. It is a thing to work for in all fields, tapping all sources of help, from the truly religious impulse to the purely philosophical ethical creeds, whatever the bias or belief. But this approach hardly promises a speedy solution to even the most sanguine minds or the most inspired individuals or groups, and from my point of view we still have to consider disarmament in the literal sense, imposing checks upon war until that happy time when, no longer necessary, they have become mere sociological museum specimens of man's organisation against his own foolish failings.

Disarmament defined in the limit as total absence of armament is a very interesting condition ; at the present time it is one which cannot actually exist in practice. Under modern industrial conditions the most pacifist country contains many important elements of potential and some of actual armament, of which the previous chapter supplies frequent examples. The question at

once arises, therefore, whether this fact alone makes disarmament impossible, or too hazardous. So far as known armament is concerned, this is already answered. The processes of industrial conversion for armament production are, even under the most favourable conditions, too slow to allow a totally disarmed country to violate the peace of the world by large-scale hostilities, and to surprise it in the attempt. This answer I am satisfied is good to-day, but will it hold good to-morrow? In other words, is there a likelihood of new forms of armament to which the facts of research and production lag do not apply? Is there a chance that inventions may develop which may spring from conception to large-scale production in forms available for offence in a few days, or at least in much shorter time than has been possible hitherto? I think the fair answer in the light of present knowledge is that such an event is extremely unlikely, but never absolutely impossible. This being so, it must be taken into account and guarded against in any disarmament scheme. Further, I intend to deal with this point later on in its proper place.

However, even if we find that it can be dealt with satisfactorily, two questions arise. Could this absolute minimum of armament be adopted at present in principle? If so, how could it be operated? The answer to the first might be regarded as a matter of opinion, but, even so, it is extremely likely that there would be practically unanimous agreement on the difficulty and present impossibility of total disarmament. The existence of large populations in a semi-civilised condition, and the disturbed state of at least two great nations, for example, render it necessary that Powers genuinely wishing to disarm should not become helpless. By so doing they might conceivably delay the peace organisation of the world for many generations. For example, it has at times seemed to be the avowed intention of the Russian Government to impose its political system upon the rest of the world by any means whatsoever, employing force if necessary when feasible. Now, it is perfectly clear that one of the objects of disarmament is to prevent any such arbitary imposition of the will of one nation upon another. From the logical point of view we are not concerned with the nature of the Soviet system, whether it be ideal, as some say, or the reverse, according to others. The point is that world peace must not be disturbed by any individual national aggression, whatever its inspiration or objective, and disarmament clearly must not be of such a nature as to make this possible. It cannot at present be total.

THE SAFETY LEVEL

For reasons such as these we see that a disarmament scheme must not at any given time reduce armament lower than a certain definite level of development, which I will call the safety level. This is at present unduly high owing to certain disturbing factors. If and when we arrive at a general disarmament programme in operation, each nation will clearly have had to consider its own local problems in deciding the measure of disarmament which it can undertake. In other words, the safety level will vary from country to country. There are three main standards by which to measure the safety level.

The first is the relative security of any one member of the disarmament scheme in relationship to other members. This standard at once introduces a number of regional problems. The nature of warfare remains such that the possibility of rapid successful large-scale hostilities is still bounded by questions of distance, common land boundaries, intervening seas. It is not yet, nor may it ever be, a practical proposition to bring a great campaign to finality by means of air alone. If we consider any one of such regional problems, it must be clear that the parties involved could attain a so-called armament equilibrium directed towards stability of national interests within a wide range of armament capacity, but the ideal for disarmament is the minimum of such capacity. In other words, although the problem is regional or local, yet through its military relationship with other regional groupings it must to a certain extent be governed by armament capacity elsewhere. This means that at some point in the system a national standard of capacity must be established, by which other national capacities will be adjusted. Unless such a start can be given, discussions will be endless.

The logical demands of the situation, and the best practical method of approach, is to arrive at the minimum armament capacity for the country or countries which are to retain the maximum armament. By this means we would reach a minimum condition all round consistent with the objectives of disarmament. Thus, in the case of land armament, the base upon which the pyramid of disarmament should be founded would be the agreed armament for that country which, by virtue of population, land boundaries, susceptibility to attack, interests involved, and in general, geographical, economic, and political factors must possess the maximum armament for its minimum legitimate needs.

In Europe, for example, without going into recent politics and the claims of Italy, the standard would presumably be set by the capacity retained by France and Germany. They would agree to reduce their armament, including trained combatants, to such a condition that a rapid decision in a great war between them was a physical impossibility. There can hardly be any doubt, for example, if they reduced to the order of magnitude allowed to Germany in the Treaty of Versailles, this position would be attained. But seeing that reasonable security is also one of the logical objectives, it might be that the quantities lie intermediate between the present German and French positions. Perhaps the adequate defence of their natural land boundaries for a reasonable period could not be assured by figures of the order of the present German capacity. In any case, compared with the 1914 position in combatants and armaments, both parties would reduce far below it, and, with this position as a standard, the military situation of other European countries would undoubtedly allow extensive reduction far more consistent with their immediate security and freedom from aggression than ever in the past, and contributing to the main objective of making a great European outbreak, regardless of peaceful methods of settlement, a practical impossibility.

Second, the ability of the group through its total war facilities to impose any sanctions or penalties upon a recalcitrant member, and, thirdly, the relationship of the group to nations not included in it, would have to be considered. The third standard, of course, becomes of diminishing importance as the disarmament scheme extends its scope to all the nations of the world.

THE DANGER LEVEL

Above this safety level we can clearly envisage an upper or danger level, beyond which armament development is so advanced as to remove us from a position of disarmament at all. For example, further intensive development of American and British naval armament, or of Russian and French land forces, would create such a situation. There is thus in the scale of armament development a kind of range between these two levels, in which range we have a condition of disarmament which, it will be remembered, is defined as giving such a definite check upon the outbreak and successful pursuance of a great war as to afford adequate time and

opportunity for the forces of arbitration and peace. The nearer we move to the safety level, the more complete will be the check. These two disarmament levels are of course simply a useful working hypothesis ; they do not represent points which can be defined in actual scientific terms. There will be differences of opinion, obviously, but I think there is no doubt that it will be possible for each country to substantiate on technical lines the armament equipment which it must have in order not to fall under the safety level. It will also be possible to establish whether any agreed armament distribution amongst the nations really places them above the danger level. I mean that the armament facts would enable a reasonable judgment to be made on this point.

It may be argued that so long as national war capacities are adjusted in the agreed ratios the actual quantities are immaterial from the point of view of disarmament and the stability of peace, but this is not so. With armament above a certain level, recognisable but difficult to define, as it was in France and Germany in 1914, it is a physical possibility for one country to reach a quick decision, even if the opponent has kept abreast in the armament race ; witness the position before Paris in September 1914. The actual victor may be in doubt, but, either way, one is possible, the military machine being adequate to carry the affair to a conclusion. But the same two nations possessing only a small fraction, say one-twentieth, of the 1914 military capacity would have very little hope, if any, of a sharp success, and the chances of settlement by the machinery of peace would be vastly increased. All kinds of considerations lead to this conclusion, all related to the general relationship between the striking military machine and the other opposing elements of resistance which exist, the longer time factors in war potential. A colossal war machine may quickly sweep them aside or overwhelm them, just as the German army did to the Belgian and French fortress defences. To a small army of a hundred thousand men these would have represented a practically insuperable obstacle, certainly in the minds of any staff proposing war. With such minimum forces, all the checks of international sanction, covenants, and resentment would loom very much larger ; it would be madness to entertain the hope of a rapid decision against the industrial country equally well armed ; the support of regional allies, as in treaties of the Locarno type, would become much more effective, and the inducement would vanish.

Thus in technical disarmament the broad considerations emerge of the importance of quantity and type, the possibility of effective disarmament, the impossibility of total disarmament, the standard of the safety level, and the vital importance of the lag in armament production. With these in view, we can pass on to consider the more practical questions of normal disarmament.

CHAPTER VII

APPLIED DISARMAMENT: NORMAL ARMAMENT

The Problem of Private Manufacture and Trade : Private Armament Industry and the League : The Non-Producing Country : Possible Solutions : The Weapons to be Limited : Production : The Magnitude of Producing Capacity : Peace Equipment : The Treaty of Versailles

The problems of applied disarmament in normal armament emerge in the answers to two questions. We have before us a range of items of armament, some true weapons, such as the machine-gun, and others, essential accessories or complementary units, such as the gun-carriage or sound-ranging devices. Further, for each such item we are faced with a development process, sometimes rooted in the peace activities of a nation and passing through various stages to reach maturity in bulk supplies of complete units for war. The two broad questions which relate to applied disarmament are as follows.

What actual articles, items, or weapons are to be subjected to conditions of limitation? It might be necessary to consider all weapons, but in practice it might be found that a chosen few were capable of exercising a critical or key function in disarmament. Secondly, having arrived at a proper choice of such items, then each one involves a process of development. What stages of this process must be subjected to control? Again, it may prove that the whole life of a weapon need not come under consideration, and that a check on certain critical stages, perhaps the last step of supply, might be effective. In attempting to answer these two questions, the main practical problems of normal disarmament will clarify.

Before proceeding to study these questions systematically, however, it is necessary to examine a special matter which cuts right across the rational consideration of disarmament, and which, if ignored, would confuse the whole issue. This is the private armament industry. The whole question of rational disarmament is based on an assumption which is so obvious and axiomatic that it is rarely stated. Nations cannot honour covenants which

imply strict control of certain national activities unless the latter are capable of, and subjected to, such control. Purely commercial operations are substantially free in all great countries, with the possible exception of Russia. Nations allow economic law rather than internal legislation to govern the development, production, and economic flow of commercial commodities. There is, of course, indirect legislation, as through tariffs, but not the positive control which attaches to ownership. If Britain wished for some reason to enter an international arrangement whereby her covenants required that the home production of artificial silk or Portland cement should be reduced to a fixed tonnage per annum, I believe it is true that without new legislation she could not honour such a covenant. She might induce or encourage, but not enforce. On the other hand, the industries themselves, with certain very limited exceptions, such as trust legislation in some countries, would have very much greater, if not complete, liberty to submit themselves to control under commercial arrangement, and there are many examples of such agreements in varying degrees, from process sharing to output allocation, almost always based on proper commercial motives and directed towards valuable objectives, such as efficient use of raw materials.

This freedom from national interference applies to the armament industry, supplies from which are not governed in origin, quantity, or destination by national policy, and are in principle outside any international disarmament organisation unless and until they are consciously brought into it. Thus at the present time we might find a nation agreeing to limit her tank production below a certain total, and able and willing faithfully to operate this limitation in controlled establishments such as arsenals, but at the same time there could be a commercial production and trade in tanks completely defeating the conception of national capacity and quantity, both in the country of origin and the one supplied, making disarmament a farce. For these reasons we must first consider this special problem.

THE PROBLEM OF PRIVATE MANUFACTURE AND TRADE

The problem of private manufacture and trade in armament presents many difficulties, but it has got to be faced sooner or later. A solution must be found, not only in relation to disarmament, but also in the direction of an equitable process of adjustment of the financial and labour interests involved, should

such be necessary. But it must be realised that this problem is simply an acute example of one very general aspect of disarmament.

It is, of course, not only a theoretical problem, but even to-day a most practical one. It would be a very interesting matter to survey all hostilities since the Great War and see how far they have been fed by the private armament industry. The point can be focused by the recent annual statement of a great and respected armament firm. We learn of submarines supplied to foreign navies, a gunboat and submarine depot ship for others. An important order for 75-millimetre anti-aircraft equipment, complete with fire-control apparatus of the company's patented design, has been received from Turkey. Work is proceeding steadily on experimental army equipments which will enable a complete range of land armaments to be offered, and reference was made to tank, gun, and shell manufacture. While mentioning this recent statement, I cannot refrain from digressing to show the light which it throws upon the international dissemination and disclosure of new armament types, a subject which we deal with elsewhere. In discussing the effect of disarmament upon the firm, reference is made to the way in which during the Great War the private armament firms not only placed all their resources at the disposal of the Government, but handed over to other Allies secret designs which had taken years to prepare, the experience and expenditure of a generation being thrown into a common pool. Surely the sale of special equipments of new designs to Turkey and other countries also represents the pooling of national armament development, not only amongst former Allies, but in a much wider field. It must be said that in this statement a very logical view was taken of the incidence of disarmament schemes upon private armament activities, and the need of corresponding adjustment was carefully explained. We are not in any sense casting the slightest reflection upon the armament industry, but simply pointing out the features which characterise it in relation to the problem of rational disarmament.

In principle, any disarmament measures will materially affect two kinds of organisation and interests, official and private. The national task of adjusting its official personnel, equipment, and organisation in a manner consistent with its covenants under a disarmament scheme, although it may be difficult, does not present such a complicated problem as the effective and equitable treatment of private interests. It has perhaps not been fully

recognised that private manufacture introduces the same difficulties into rational disarmament as certain other matters which have been admitted and ventilated. For example, with regard to combatants, it has been clearly appreciated that, under a scheme involving their limitation, all semi-military organisations for military training outside the scope of the scheme represent an illogical, a dangerous, and disturbing factor which was dealt with in a drastic fashion as regards Germany in the Treaty of Versailles. It was fully recognised that it would be futile carefully to list the permitted number and type of combatants allowed to Germany, as was done, and to ignore the vast reserves which could be built up in other organisations of a private kind which differed only in name but not in nature.

But the fact that private arms manufacture deals with materials and not with men, and that it carries large vested interests openly and properly based on the normal economic structure of a country, makes no real difference as regards the logical requirements of disarmament, and the latter must not be confused with the special problems of readjustment which, although of the utmost importance, should not in any way prejudice the rational consideration or operation of disarmament proper. Let us consider in turn the theoretical requirements of disarmament in relation to the private armament business, the international measures which have been considered or proposed so far, and any conclusions which emerge.

It must be perfectly clear, and a matter of common agreement, that, to operate armament limitation efficiently, there must be some reasonable assurance that the plan is operating in actual fact besides being approved on paper. This means that the sources of armament production must be known to, and under the control of, any nation in question. For instance, no country can properly co-operate in a general scheme of armament limitation unless it can supply the correct information to, and when and if necessary, assist inspection by whatever central organisation may be agreed. If, for example, we as individual nations in an international scheme solemnly agree to a definite producing capacity and stock of 15-inch howitzers, we must obviously first know the whereabouts and quantity of both production and stock, and definitely eliminate any existing or future excess. The private manufacture of armament at once arises as a problem. I will assume for the moment that nations have no intention of violating their programmes of armament limitation, such agreement having

come into being. Can they definitely honour their bond if private manufacture is generally allowed? Clearly they cannot do so if such manufacture is uncontrolled. Suppose, for example, that we have a definite capacity allocated to us in accordance with an agreed disarmament scheme, and we decide, and clearly expose, as may be necessary, the nature of that capacity—where it is to be found and all other relevant facts. Let it be composed of certain Government establishments, such as arsenals, and the whole or parts of private works. Now the latter element of capacity, if uncontrolled, is undetermined, for two reasons. First, it will be exceptional, rather than the rule, in time of peace, that replacements for given national quota of heavy armament will absorb a fraction of the capacity of a works designed to produce them. That capacity is destined to yield a certain amount of armament for peace alone, or at the most for the type of hostilities permitted within the disarmament scheme, at which time it feeds, so to speak, a consuming market. But in times of peace that production can only be used to replace obsolete types and meet a wastage caused by practice manœuvres and other time factors, which are very slow. Such a private factory, governed essentially by commercial standards, must therefore find markets for its production, and these cannot logically exist in the country concerned without disturbing the agreed amount of armament. The possible solutions are threefold : i.e. use of the plant for peace products, export of armament, or subsidy. Taking these in order, the first—peaceful outlets—is only possible in some and, I think, a minority of cases. We have the authority of General Sir Herbert Lawrence, the chairman of Vickers Ltd., who at their 63rd annual general meeting said, " The shareholders in armament firms cannot be expected to maintain that reserve capacity for the benefit of the Empire unless reasonable compensation is paid, nor can such firms train up the skilled workers and staff required unless sufficient work is found for them.

" We cannot ' turn guns into ploughshares ' without scrapping practically the whole of the plant required for the production of guns, and substituting for the workers accustomed to gun-production other men trained from youth in the manufacture of ploughshares. On that aspect of the question I can speak with authority."

Therefore, the rapid turnover from armament to normal commerce, or, indeed, the frequent alternation between the two, cannot be the general solution which the argument requires.

The second suggestion—export—clearly contains a fallacy. In terms of one nation it is feasible, but, viewed in the light of a general scheme of disarmament, it proves untenable. Consider, for example, any one feature of armament—say the machine-gun. Each nation has a definite agreed capacity and stock. Adding the latter, we reach an international total. How can any country export machine-guns without disturbing and adding to this total? It can only do so if some other country dispenses with the privilege of producing capacity, reaching its quota by means of imports. Two questions at once arise. First, is this position likely to exist; and, secondly, could it be relied upon to absorb just those amounts requiring to be exported? An affirmative answer is extremely unlikely to both questions.

Later on we deal with the question of the non-producing country under a disarmament scheme, and it might be said that such countries would absorb the export surplus. But here again we have a fixed market, even if it be an export market, governed by armament allocations. Quite apart from the fact that the private producing capacity in the country of origin would disturb the official agreed capacity of that country, such export could only solve the commercial problem of maintaining output if it so happened that there was a nicely adjusted balance between private output and official requirements of the non-producing countries. But, even if we obtained such a balance, how long would it continue? National policies change, non-producing countries may produce, disarmament quantities may alter, and a private factory could not stabilise its production with even a fraction of the certainty which governs business risks in the sale of a commercial product in the markets of the world. The second solution of uncontrolled export, therefore, cannot be regarded as adequate. We come to the third, and last, which is subsidy. But as soon as a country subsidises idle or relatively non-productive capacity in order to ensure its quota, as occasion demands, the plant becomes in fact if not in name an arsenal, managed by a company under a contract which limits production. It thus becomes abundantly clear that the private, unimpeded manufacture and trade in arms is logically incompatible with a rational disarmament scheme.

PRIVATE ARMAMENT INDUSTRY AND THE LEAGUE

The members of the League of Nations were in most definite agreement, in Article 8 of the Covenant, that the private manufacture of arms was open to grave objections, so much so that one of the tasks of the Council was to "advise how the evil effects attending upon such manufacture can be prevented." This matter was taken up through the normal machinery of the League in 1921 by the Temporary Mixed Commission, which proceeded to summarise the objections to untrammelled private manufacture of arms. These were, very briefly, the fomenting of war scares, exercising undue influence on Government officials, stimulating the armament race by false information, the control of newspapers to mould public opinion towards armament needs, and in general the various reproaches which have been levelled against certain great armament firms at different times. But, although their activities have been painted jet black, there has been much exaggeration, and, apart from certain clear exceptions, which arise in the best regulated of industries, most of the so-called abuses are simply normal commercial activities applied to armament commodities, which would have a much less serious appearance if the products were those of peace, and subject only to criticism against general standards of commercial morality.

Even if we ignore all such episodes as the recent case of Mr. Shearer in the U.S.A., or the pre-war Press activities of Krupp and other armament firms, and even if we assume the existence of a private armament industry carried on under the standards of the highest commercial integrity, which may well be true to-day, we are still left with a situation open to the gravest objections. It is not a question of malicious intention, but of inherent factors, and armament firms with an open world market cannot help stimulating the armament race, however pure may be their commercial procedure. Their legitimate commercial propaganda may produce undesirable results, and their motives, however good, will unfortunately always be questioned, and, indeed, in danger of leading to gravely undesirable results. The fallacy lies in the existence of an open market for arms, and the real objections are not those listed by the Commission, as can be seen by the fact that the situation would not be substantially changed if those listed objections were eliminated. The real trouble of private manufacture is one which attaches to the most perfect and

scrupulous of firms ; unrestricted private manufacture is not compatible with rational technical disarmament ; it must contribute to armament progress and the armament race, and it is not consistent with world peace based on a scheme of arms reduction and equilibrium, which it destroys.

The Temporary Mixed Commission, in submitting the objections to the Assembly, proposed certain measures of control which were, very briefly, the prohibition of export or import of arms except by licence, central publication of these licences, no manufacture without one, ownership of shares to be known and named, no parallel shares in newspaper companies, and, in general, measures designed to give greater knowledge and control of the activities of armament firms. But it does not appear that these proposals were related to any scheme of armament reduction and limitation, which is the crux of the matter. The Commission, under instructions from the Assembly, arranged to prepare a draft international convention on private manufacture, and in 1924 a sub-committee met in Prague for the purpose, but the Assembly and the Council deemed it advisable that the draft should await the results of the 1925 conference on the supervision of the commerce in arms, where the situation of the non-producing countries came forward strongly, and it was decided to ask the Governments to examine the international aspect of the manufacture of armament as soon as possible. The broader issue was now appearing.

The work of the Temporary Mixed Commission was continued by a committee of the Council, which, after consulting various Governments, drew up a draft convention, but the difficulties which they recorded showed that the true and much wider bearing of the problem of private manufacture was emerging. It was beginning to be asked why State manufacture should not receive the same control and publicity, and at the 1926 Assembly various nations drew attention to the close connection between the proposals in the previous conventions and drafts, and the central problem of armament reduction. It would seem, therefore, that although the League has officially faced and examined this problem, and has made considerable progress towards a convention which would eliminate the important but narrower disadvantages or evils of the industry, it has but recently begun to deal with the whole broad question of the incidence of private manufacture and trading in arms upon the working of a general Disarmament Treaty.

It would be presumption to suggest that the League is not fully aware of the logical needs of the situation, but it is our duty to examine them here. We start off from an international situation in which all the members have agreed to limit their armament equipment to definite maxima in agreed ratios determined by negotiation or compromise as to national needs. They not only include existing quantities of armament within their scheme, but also, and logically, stocks not yet allocated to cadres, but related to peacetime replacement and permitted mobilisation reserve, if the scheme allows such. Also, within the scheme, they agree to limit their official productive facilities under international control, relating their equipment to the permitted needs of peacetime replacements, or any other legitimate and agreed requirement.

Under such a position as the above, the place of a private armament industry on pre-war lines is clear. Manufacture and sale in the world market under a purely commercial stimulus would totally defeat the Disarmament Treaty, and the simplest course—in fact, the completely logical course—would be the abolition of private manufacture and trade in arms.

THE NON-PRODUCING COUNTRY

But, unfortunately for a simple theoretical solution of our problem, the situation which I postulated above is not the actual one. There are nations which could not meet the supply needs of armament up to the agreed limits of the Treaty from their own sources of production. But it is an essential of the Disarmament Treaty that these nations should be equipped within the Treaty limits, and it is as important in reason that they should possess the agreed equipment as it is that no nation should seriously exceed it. This has therefore been made an argument for the continuance of the private arms industry and trade, but it is not necessarily so. If this argument were applied without any qualification, and without, for example, any restriction on the production of the private armament industry, it would mean that in order to assist certain of the less military nations to take part in a Disarmament Treaty we would have to adopt a measure which more or less made the whole Treaty useless. In other words, this argument, unqualified, reduces the whole matter to an absurdity. The only reasonable course is squarely to face the

question as to how such nations are to be supplied and equipped in a manner consistent with the maintenance and stability of the Disarmament Treaty. There are three ways in principle in which this could be done : the development of armament industries in the countries requiring supplies, the supply from official sources of production, such as arsenals, in other better equipped countries, and the supply in the old fashion from private firms in other countries. Let us consider each in turn.

We should with reluctance encourage the development of new armament industries in countries which do not now possess them, for one of the objects of disarmament is gradually to reduce total armament producing capacity, and it would be a pity to move towards this objective by a preliminary increase. It is hoped that the reducing process would go on as the influence of peace ideals, organisation, and confidence made themselves felt in the world, and that process would gradually tend to bring the present ill-equipped countries on a level with the others in relation to their quota. It would seem that the best solution, therefore, if nations are willing to remain with inadequate productive capacity, would be to supply their needs from other sources justly and properly in a manner consistent with their security, in the hope that such supplies would gradually become less necessary with the process of further all-round reduction. This brings us, therefore, to the consideration of the two other methods: official or private supplies from other countries.

The governing consideration as regards such supplies is that they should be produced in such a way as not to interfere substantially with the agreed distribution or equilibrium of the various national productive capacities. For instance, if we took the total armament requirements of all the countries which under the scheme had to purchase externally, and if we satisfied that total demand from official or private manufacture in one country only, it would almost certainly place that country, as regards productive capacity, far and away above its agreed capacity under the Disarmament Treaty. It would be extraordinarily difficult, and, I think, wrong, to assume that the country in question could in some way segregate this extra capacity so that it would not in any circumstances, such as the outbreak of war in defiance of the Treaty, employ that capacity for its own ends. It therefore seems essential that, in arranging for supplies to non-producing countries, the capacity required to meet that supply should be spread over the producing countries in a manner or

ratio reasonably consistent with the general allocations under the main Treaty. The question therefore arises whether this can best be done from official production or private armament industry. There are no two answers to that question. To meet this requirement, it could only be done from official sources, and private manufacture could only be contemplated for the purpose if it were so regulated and controlled as to remove from it all elements of commercial freedom and make it in all else but name, and possibly ownership, a State concern.

There is another consideration which logically leads to the answer that the non-producing countries should be supplied from official establishments. It is perfectly clear that the moment we reach a position of agreed national armament-producing capacity calculated to meet peacetime needs, and certain limited production which might be required in the event of agreed hostilities, then the factories in question must have tools, machines, and productive capacity able to produce considerably in excess of peacetime requirements. To maintain such factories for long periods with a great excess of potential in relation to actual output is not a commercial proposition. Remove the open market and you make it impossible in most cases for private firms to carry on without special arrangements or subsidy. Private capital cannot maintain plants which are only working for long periods at a fraction of their possible output. There will, therefore, be excess and subsidised plant lying idle in official establishments, and it is logical to employ this to meet the needs of the non-producing countries, and possible to do it still within the principles and ratios of a Disarmament Treaty, whereas the contrary applies to purely private sources of armament manufacture.

Of course, these logical considerations at first sight introduce objections which might be raised by the non-producing countries which formerly bought, and are probably still buying, from private firms in other countries, and they cut right across important private interests which must be heard. Such a non-producing country might claim that the secrecy of its purchases was impaired by transferring its orders to official establishments. But what is that secrecy ? It concerns the quantity and the type of armament. As regards quantity, there cannot under a Disarmament Treaty be any more secrecy. The whole object is to restore and maintain confidence and world-peace by adopting agreed and reduced armament quantities under a system of publicity through some central organisation.

As regards secrecy, we can appreciate that a non-producing country, although reconciled to the loss of supply independence, might want to retain its initiative as to any new types which it might evolve. But is there anything in this point? In the first place, it is increasingly improbable that in the future such relations would exist between a Government and a private firm on its territory as to allow that firm to produce some improved or new weapon for another country and keep the matter entirely secret from the Government in question. Again, it has never been a characteristic of the trade in arms, even in the past, for a private firm to refrain from exploiting a new weapon in all possible directions. Further, it is an intolerable thought that one's own countrymen should in secret be producing quantities of some deadly weapon for another country, giving the latter some critical advantage over one's own country in the event of war by a breach of the Treaty under which supplies have been made. It is entirely inconsistent with international confidence and satisfactory relations in the direction of peace that such a situation should be possible or permissible.

This point is emphasised by the extraordinary contrast between the policy and position of a private armament firm during peace and in times of war. In the latter, the private industry falls into line with the national arsenal. The position is at once adopted of devoting every fraction of initiative and effort to the furtherance of the national cause with the most rigid exclusion of any assistance, by way of ideas or supplies, to the enemy. The private firm is bound willingly, and presumably legally, by the same ties of intense patriotism which govern the individual soldier on the battlefield. Any action by way of armament which prejudiced the safety or success of the soldier and the army would be inconceivable, a matter of national censure and dire penalty.

Yet, move from war to peace, and the most complete liberty of action in the private armament industry is unfolded. Broadly speaking, and in spite of the personal feelings and private influence of some of the more public-minded armament leaders, the purely commercial motive rules the field, and, although this is so, we cannot in common fairness criticise the personalities of the industry for that reason. It is the circumstances which they do not or need not mould which govern the situation, and thus, through the casual commercial incidence of armament supply in peace, a situation can be created which in the last analysis may prove disastrous to their own country by contributions to foreign

armament which in time of war would be utterly impossible. Thus the assistance given by the House of Krupp to Germany was of untold value in terms of armament, but the international distribution of its products has probably resulted in the mutilation of tens of thousands of good Germans. Great as the assistance of the firm of Vickers has been and still is to British armament, yet international distribution of one of their products, the Maxim gun, has been responsible for the death of hundreds of thousands of Englishmen. Under the given circumstances, both Krupps and Vickers were powerless to prevent these results, for neither could have been expected to take a longer and loftier view than their own Governments, especially when its consequent action would presumably have been a great reduction in their commercial activities to such an extent as to render such management impossible. We cannot avoid the conclusion that there is as yet in the organisation of society or of peace nothing to prevent the private armament industry of a nation unwittingly or fatally, through a chain of events, turning its own weapons against its own flesh and blood, and the fact that we cannot criticise the industry for such results is in itself the most powerful criticism of our lack of international policy and organisation.

But there is a wider consideration than this which applies to and overrules any objection on the grounds of secrecy from a non-producing country. It will be seen later, when we come to discuss the new agencies of war and the evolution of armament, that rational disarmament is going to impose upon us more and more the need of considering equilibrium and stabilisation of armament type just as much as, if not more than, armament quantity. It is without any doubt going to be essential, in moving forward in this question of peace organisation, for the different nations to adopt a policy certainly of relative standardisation, and possibly of restricted or even forbidden development of armament type, if the general Disarmament Treaty is to have real meaning and value and be anything but a momentary solution or a farce.

Under such conditions the question of secrecy would become much less important. It would resolve itself into minor differences, such as those of calibre, weights, or shape, but the basic principles underlying the weapons would be so similar as to eliminate any question of secrecy as a decisive military factor. In any case, if this question of secrecy led the non-producing countries to reject a solution in terms of supply from foreign official establishments,

it would be better for them to be left to create their own armament industries within the agreed limits, if they so wished, rather than introduce the instability of the old form of private armament supply.

If the world moves towards any disarmament schemes which demand and embody restrictions in the commercial freedom of the private arms industry, or more drastic measures of control or prohibition, it would be the grossest injustice if the firms and interests in question were not fairly dealt with. It would be absurd to colour any policy of compensation or adjustment by the suggestion of the supposed reprehensible characteristics of the armament industry. These firms have operated in a legitimate manner, and have given their nations and the world the services required of them with great zeal and efficiency. The situation is simply that an industry with important, vested, and widespread interests finds itself threatened by new forms of international policy and organisation. It finds its commodities and activities likely to meet with a decreasing demand, not from any normal commercial or economic reason toward which it could react in the ordinary way, but from more arbitrary causes which may compel drastic and sudden changes, accompanied by great loss, unless adequately taken care of by compensation or assistance to adjust to other manufactures. The situation of the clashing of a private interest with national policy has arisen before, and will arise again, and there is no reason why in this case the same equitable adjustment should not be applied as in any other case having nothing to do with armament.

POSSIBLE SOLUTIONS

It is of interest, and perhaps valuable, to consider what kind of solution could be found for this problem of private manufacture and trade in arms to meet the two fundamental conditions, first, that any such private activity should in no way nullify or be inconsistent with the agreed allocation of arms and sources of production, and, secondly, that the private interests of finance and labour which have evolved with this industry should suffer the minimum hardship in any re-arrangement.

Let us first make it clear that the mere fact that private capital supports, and therefore that private profits are made from, the arms industry, does not by itself have any incidence upon the

question of disarmament, which only arises when those private interests assume the wide freedom of production and sale associated with any other non-military and commercial commodity. For instance, in the Treaty of Versailles the German sources of home arms production were limited to approved, known factories producing approved weapons, but it was not stipulated, nor presumably was it regarded as important, that those factories should be owned officially, and not in the hands of private capital. Presumably the Allied and associated Powers were satisfied that, whether or no the factories belonged to the State, the latter could sufficiently control them so as to honour its covenant, and, if this be so, it could apply equally well to other countries under a general disarmament scheme.

The question which then arises is, How could the private arms industry be organised so as to retain those elements of independence such as financial control which were still consistent with such a scheme? and, if it is thought that disarmament is a serious possibility, this is a question which it would be wise for the arms industry to consider in advance, although it may be presumption to suggest it. The requirements are that such national production should be inside and not outside the agreed national quota and ratio, and, secondly, that the supplies from such production should be directed to the non-producing countries, or partially to others in such a way as not at any time to disturb the agreed quantities of armament possessed by nations under the scheme. The latter provides for the central control and decision regarding both points, production and distribution. The simplest theoretical solution, therefore, would be for the arms industry equally to centralise by a combination or amalgamation so that it would become one private organisation producing and supplying the deficiencies between quota and home production from national plants whose location and magnitude were arranged so as to contribute to the agreed national quota. This indicates, of course, an international arms organisation, or several, covering different sections of armament, working hand in hand with a central disarmament organisation, such as the League of Nations. In this manner it would at least be possible to readjust the private arms business with the least hardship to the private industries concerned, and with the important advantage—a commercial essential—of some sort of steady market and programme thenceforward.

Even if it were feasible, it still leaves the problem of supplies

to nations not included in the disarmament scheme, and it is again perfectly clear that the principle of non-interference with agreed ratios of production would again compel the central allocation of such outside business. This should not be difficult so long as the organisation was such that the benefit to shareholders was independent of the particular factory involved, which position finds a frequent parallel in ordinary commercial enterprises of international scope. From the widest disarmament point of view, however, this question of armament supplies indiscriminately to nations outside the disarmament scheme requires consideration, and we can focus the point by considering the recent announcement of the supplies of British tanks for China. All kinds of perplexing points arise, from the narrowest personal to the widest international bearing.

From the more narrow personal or national point of view the situation is somewhat as follows. The tank became a saleable commodity for China or any other country not only on account of efforts made in armament factories. We have already seen how the British tank, for example, passed through numbers of different types before it was regarded as satisfactory, and it was not only work on design and production which made it so.

General Charteris, in his *Field-Marshal Earl Haig*, refers to the first use of tanks in the Somme battle, justifies Haig, and says, "Moreover, however careful and far-seeing the design and tactical use of a new weapon may be, nothing except actual experience in battle can fully disclose both its strength and its weakness. It was better to test the new tank in its present numbers before the whole resources of the factories were committed to the present design."

Each new design was the result of battle experience, which really meant a number of vast experiments paid for by the bodies and lives of thousands of individual soldiers working or tactically co-operating with tanks.

The same point is illustrated by the British cloud gas attacks. In the front line, just before zero hour in the Battle of Loos, many of us—the units operating gas and the infantry—were compelled to swallow large quantities of chlorine gas with painful and sometimes fatal results. We were testing in battle a new form of armament, a new system of conveying gas to the enemy, and it was faulty, releasing gas in our own trenches. Men operating gas had to abandon the appliances or carry on, and they did the latter. As a result of their experiences and expert observations

vast improvements were made, and those contributions, had they occurred in business instead of in battle, would have involved an equity, an interest in exploitation, in some form. In general, all new forms of armament employed in the war owed much of their later design and success, and their future in peace, to the ordinary or the specialist soldier, overwhelmingly the present civilian. They at least, or their survivors, are entitled on the broadest grounds to some say in this matter. If the issues were purely commercial the point could be ignored, for ordinary legal codes provide no means for soldiers to be rewarded for their contribution to armament design except in very special and privileged cases. But armament unfortunately is a special type of commodity which has unusual bearing on national policy, and whose distribution may in the limit produce further wars, to the detriment of that unfortunate type, the individual soldier, whose battle experience contributed to the weapon. I do not wish to exaggerate the importance of this particular case of tanks to China, but it is amusing to follow up its possibilities. Chinese Governments have been notoriously unstable, friends now may be enemies to-morrow, and it would not be impossible, if we shipped a large number of our best tanks to China, to find them being used against our friends and relatives in various settlements, or even in a more serious and organised fashion against our land boundaries in the East. The same comment would apply to French armament supplies to Chinese factions. We can visualise the danger developing on such a scale as to bring us in again as individuals rallying to national defence and being decimated by the use of those very weapons which we had fostered in war, and which a purely commercial armament trade had made available to our opponents. The average soldier, i.e. the average citizen who sacrificed much before and would be ready to do so again, seems to be entitled to have a view on this question.

From the wider international point of view it is extremely problematical whether it is advisable for the great nations, members of a disarmament scheme, to educate others in the use of the new and potent types of armament. The argument that if one nation did not do so the others would, and thereby gain a commercial and perhaps a diplomatic advantage, is trifling in comparison with the importance of the whole matter. While approaching and preparing for the thorough consideration and operation of a disarmament scheme, surely the only policy, and a feasible one, is to discourage the dissemination of, and increased

experience with, new types, which may later be the subject of drastic limitation. The example of China is perhaps unfortunate, as that nation is a member of the League of Nations, and has presumably no equipment of tanks, and if the latter were present in the final agreed allocation of armament, no doubt China would at least have the opportunity of being supplied as a non-producing country. But this does not invalidate our general argument.

It is abundantly clear that, before the requirements of normal disarmament can be considered, the question of private manufacture must be disposed of, and in such a way as to satisfy one fundamental condition. It must not interfere with, or must be merged into, any agreed international allocation of armament production, or distribution, which may be adopted. We therefore assume in what follows that the problem of private manufacture has been dealt with in some such way.

THE WEAPONS TO BE LIMITED

This simplifies the question before us. Having agreed a ratio amongst the nations, to what elements in armament potential must it be applied? The objective is to provide sufficient armament to meet the minimum agreed defensive requirements of the countries concerned, but insufficient to allow the possibility of successful large-scale surprise hostilities and the breaking down of the mechanism of arbitration. The latter is the governing consideration.

What weapons must be submitted to limitation? On this question a number of very simple points arise. In the interests of the simplification of disarmament clearly we should choose the minimum, for we need the least possible employment of disarmament mechanism, to reach the objective with the least interference with national activities. This is certainly true in the present mood of the world, and in any case desirable. While disarmament schemes envisage or permit the existence of armed forces and the possibility of some types of war, there will be a range of weapons and military appliances which nations will wish to retain. There may be some forms which in the near future they may abandon. But, having arrived at a common conception and agreement on the weapons which the modern army may possess, is it necessary to apply limitation to all, or are there key weapons whose limitation would cover the rest so far as results were concerned, and

bring about the desired disarmament condition? The answer to this is so uncertain, so much a matter of opinion, and any specific answer so difficult to prove, that there is only one course, which is to play for safety, this being the object of the scheme.

Is there to-day any single weapon or item of armament whose control would provide an effective check? The best military opinion would probably say that decisive large-scale wars could certainly be fought without artillery, or without machine-guns, or gas, or aircraft, or tanks. Military history is sufficient proof that the limitation of none of these alone would be effective. Could such wars be waged without some weapon similar to the rifle, say with individual weapons no more advanced than those of the Romans? Undoubtedly they could; cavalry would resume its former importance as such or be replaced by mechanised form and decisions could be reached. There is at present no individual weapon whose control or elimination would give an adequate check. To find any single item of this sort we should have to go far back in the roots of armament and choose some raw material—say a metal which had widespread and fundamental application. This point of view has been explored more from the economic than from the armament viewpoint by Sir Thomas Holland and others, but no single material or process emerges capable of acting as a universal disarmament check.

With regard to choosing the minimum number of armament elements, the governing consideration is the existence of a number of more or less complementary types, all of very great importance, which increases as the other types are submerged. For instance, if rifles were limited, and not machine-guns, the importance of the latter would greatly increase, and vice versa. If artillery were submerged, then the importance of small arms would predominate, and so on. Therefore, if we wish to simplify the disarmament problem, the real solution as regards the weapons to be standardised is to choose the minimum and apply limitation thereto.

So long as a nation can pursue its legitimate military activities without threatening the peace structure it is not very important which weapons are chosen. War can be made very complex by agreeing to employ a great variety of weapons, or, much simpler, by limiting the number of types. The greater the complexity, so we complicate our disarmament scheme, but we do not necessarily make it less effective. There is not much point in this discussion in trying to define which weapons should be employed

for such activities, for that will obviously be a matter of compromise between the views of the different military staffs of the nations concerned. So long as there is strict uniformity of type in the different national armament equipments the condition of reduction and equilibrium can be attained. If disarmament were viewed in this way, it is not possible to say with exactitude the complete list of weapons upon which the different military experts would decide, but there is the governing experience of the Great War before us, and as a result of it a representative military opinion was provided in 1919 in the list of weapons which were subjected to reduction and control in the disarmament of Germany, and it covered guns, machine-guns, rifles, trench mortars, aircraft, and the relevant projectiles.

Before considering the chief of these weapons in turn we have to answer an important question. What are the factors to be subjected to reduction in connection with each form of armament? There could be no doubt from our previous discussion, and from the bulk of informed opinion surrounding and since the Treaty of Versailles, that we have to consider three factors : producing capacity, actual equipment of the armies in peace, and reserve stocks. Where, as in most cases, the weapon is composed of a projector and a projectile, they must both come under consideration, although the projector itself, because of its tactical and strategical value, and because of its long production lag, requires, perhaps, the more serious consideration.

PRODUCTION

Turning first to production, there is the important question as to what is to be regarded as armament manufacture from the point of view of disarmament. Must we deal with the manufacture of every single item which goes into the make-up of a weapon, or may we adopt the process of simplification by picking out critical items which govern the rest? For example, in a gun and its carriage there are all kinds of components which are normal features of engineering industry, such as arrangements for lubrication, brakes and linings, washers, nuts, screws. Generalising over armament production in the chief Powers, it would be true to say that many of these accessories or minor components are obtained from normal industry. For example, a company providing locomotives with small accessories may also supply Governments with the same articles for armament. It is quite clear that

if we were to carry armament reduction to these extreme lengths an impossible situation would be reached, interfering in endless ways with normal peacetime industry. A company making normal engineering parts to be used for guns is not necessarily a private armament firm in the sense in which we have used the term previously, with such vital influence on disarmament. I think we could say at once that in considering the limitation of armament production we are only concerned with the actual assembly or manufacture of the finished weapon, and with the manufacture of those parts of it which are essentially parts of the weapon and have no use in peacetime industry. In other words, if all manufacture of actual finished armament or of components which can only be used for armament are brought within the scheme, this is all that is practicable. The question arises whether it is sufficient, and this can be dealt with in considering the different weapons as it may vary in each case.

Dealing with guns and artillery in general, there can be no doubt that unless methods of production have changed radically since the Great War, then the evidence is all in favour of the effectiveness of the reduction of armament-producing capacity. If we have plants only equipped to produce the quota, so that new works have to be organised, not necessarily built, in order to increase production to allow hostilities on a forbidden scale, then the lag would be such that those hostilities would be made practically impossible within periods of twelve to twenty-four months, assuming that there were no other delays involved. The same general considerations apply to tanks. It is true that the principle of non-interference with peacetime factories would allow the accumulation of certain parts of tanks, such as the traction elements. There is, perhaps, slightly less protection than for the case, say, of a heavy gun, but nevertheless the actual fighting part of the tank, its armouring, adaptation for weapons, and the operation of building, all present a very substantial production lag.

With regard to rifles, the same considerations apply in general, although the lag is somewhat shorter ; but we must remember that we have a further safeguard with the rifle, which will increase as time goes on, and as we lose the benefits of potential combatants trained in the Great War. The rifle is a one-man weapon, and is useless without its combatant. The disarmament scheme must be based on a strict limitation of trained combatants, with intelligent and scrupulous attention to semi-military organisations which

might provide trained or readily trainable combatants. Assuming that all this has been taken care of, the fact that a rifle has a somewhat shorter lag in production becomes less important, for the coming into use of any new production would not necessarily make those rifles available for war, but only so far as there were combatants to employ them, which would presumably imply a very great increase before the organisation of peace could be threatened. The question has often been raised as to whether the widespread use of sporting rifles is a sufficient factor to influence the value of a disarmament scheme in which military rifles are subjected to limitation. No doubt the importance of this point has been exaggerated. It would seem from general, but not necessarily accurate, knowledge that the number of sporting rifles spread throughout the world is very small in relation to the colossal quantities of military rifles required for large-scale hostilities. There is the further safeguarding feature of great variation in types, requiring different ammunition, which would render it a very difficult matter to embody such rifles into a well-organised and efficient force under modern conceptions of war. Unfortunately, we have to visualise the possibilities of evasion of disarmament schemes, and it would clearly be a possible method to develop standardisation of type, and under the relative freedom of trade in sporting weapons to establish large production and stock. This leads to the logical conclusion that if such weapons are to be disregarded because of such factors, then steps must be taken to see that no substantial change occurs in the situation as to production and type, which implies national information and its international centralisation with regard to this or any allied subject.

The machine-gun situation is not so reassuring, in view of the extreme casualty-producing efficiency of this weapon. We know that the lag in production is long, but my view is that this weapon would require very special attention in a limitation scheme. It seems very doubtful whether the world requires machine-guns apart from potential war use, and it would certainly assist disarmament if there were no production of the weapon whatsoever except in relation to permitted establishments. The great question to my mind with regard to the machine-gun, as I point out later in connection with the new agencies of war, is its danger as regards disarmament through possible change in type by its approach in handling, adaptability, and weight to the typical one-man weapon such as the rifle.

We cannot fairly ignore the fact that even to-day machine-guns seem to escape the control of national authorities and come into use in private warfare, such as that so frequently reported from Chicago. Now it may be that such occasions are exaggerated and rare, but they undoubtedly exist, and the importance of the matter lies in the future, when the machine-gun will evolve, unless checked, into the lighter, but potent weapon indicated above. Such a weapon might then begin to equal the modern revolver in ease of distribution. The widespread private possession of the latter can hardly be regarded as impinging upon disarmament schemes, but substitute this new weapon for it and the conclusion is no longer true. The fact cannot be avoided, and if and as small arms evolve in type so that military possibilities and private use converge, then the widespread distribution of such weapons would become a problem of increasing and real importance as regards disarmament. For such reasons the schemes proposed in relation to statistics and licensing by organisations under the League of Nations, when considering the private trade in arms, should be pursued to their logical conclusion.

With regard to normal artillery projectiles, it is appreciated that advances in modern engineering methods might reduce the lag in production, and thus, in the case of a nation wishing to break its covenant, reducing the security which derives from conversion lag as in other cases—say the heavy gun ; but we must remember that the result or effectiveness of a disarmament scheme cannot be measured by one item alone, but rather by the cumulative effect of all the methods which are operated. The limitation of production of guns themselves would go far to neutralise any greater flexibility in the production of their projectiles. But the projectile itself is not such a dangerous element as might be supposed, because of its own complexity. When we consider all its components, such as the different parts of the shell envelope and the fuses, charges and shell filling, we get real assurance of disarmament possibilities. All these components have only war uses, and, if they are rigidly produced in known centres of agreed capacity, the question of multiplying factories to produce all these different items brings in a cumulative lag which would be effective. In connection with projectiles, the question of shell filling would logically demand serious attention in a disarmament scheme. It has been shown time after time that the rapid multiplication or development of shell-filling stations is not a quick but a laborious business, involving special delays in the training of personnel

quite apart from the normal technical delays of plant development.

THE MAGNITUDE OF PRODUCING CAPACITY

The logical process of disarmament is broadly as follows. The nations first fix the relative magnitude of their armed forces. This governs the ratios of equipment or armament, but it does not decide their actual quantities, nor the magnitude of producing capacity to be held by each. The limited national production of the mutually chosen weapons requires some standard, or at least some agreement, in order to fix magnitude as distinct from ratio. For instance, we may reach firm agreement upon international distribution of artillery formations, thereby fixing the national capacity of guns of different calibres, but how are we to decide on the size of the national factories to feed this supply? Are we to have factories which could turn out the agreed quantities in a month, six months, a year, or what period? We need not multiply examples, but the question applies to all the agreed elements of armament within the scheme. It is essential, of course, to have common agreement as to a standard, but that alone is not sufficient. Such a standard must be fixed to comply with the other principles or requirements of disarmament. The first essential is that we must not defeat the security obtainable through production or conversion lag.

We can get a clearer picture of the situation by visualising the two extreme cases of maximum and minimum security. If we assume a nation in possession of its agreed quantity of artillery, we know the factors which would normally govern its replacement in peace. They are depreciation through use in training and manœuvres, obsolescence through improvement in design, and a very long-time factor of depreciation under conditions of efficient storage and maintenance. The history of armament shows that very long periods have elapsed between the main stages of replacement of national artillery. There is no need to contemplate rapid turnover of the agreed quantities; the time, if necessary, could be ten, twenty, or thirty years; but any agreement as to period would depend on how far the disarmament scheme encouraged or stabilised improvement in type. The position of maximum security would contemplate manufacturing capacity unable to duplicate the equipment for an army, say, of two hundred thousand in less than a year, or would provide a lag of

several years to reach the strength of the great continental armies of 1914. It would impose very long periods of idleness upon armament factories, which indeed must be their main characteristic under a regime of disarmament. It must be clear, therefore, that the position of maximum security is governed by the magnitude of military forces under such a scheme. The smaller they are, and the longer the replacement interval for their equipment by means of the agreed producing capacity, the less can those factories feed an illegitimate expansion, and the more that expansion will depend upon production from entirely new factories with the maximum conversion lag.

On the other hand, if the nations find that they cannot in the first place standardise on very small military forces, so it becomes of the greatest importance to fix the producing capacity in relation to a very long replacement interval. If this be ignored, and initial agreed equipment be great, we move to a situation which provides only a momentary equilibrium and the minimum security. In this case the producing capacity, although mutually agreed, might be such that it could turn over the equipment required, or even considerably more, with the minimum conversion lag, with no obstacle such as duplication of plant, approaching the ideal position for quick arming, each major component starting its manufacturing life in its own set of machines without having to wait months to take its place in the steady use of one machine gradually fostering many weapons. In other words, the ratio, and agreement under it as to quantity of armament, are essential, but not sufficient, for they leave producing capacity undetermined, and disarmament requires that it should be fixed. It is clearly impossible for us to arrive at actual figures. None of the main facts are yet known. We would require to be told—what, indeed, the eventual disarmament conference will have to decide—the magnitude of armed forces at which reduction will be stabilised, the density of equipment in such formations, the policy as regards type, and its bearing on the interval of armament replacement. These points will presumably be settled by the fusion of expert military views, but after that is done, then it is certain that the extent to which the above principles and considerations are applied will govern how far the equilibrium attained is true or false, momentary or permanent, redistribution of armament or disarmament.

PEACE EQUIPMENT

There are, however, certain elementary considerations regarding the quantity of peacetime equipment under a disarmament scheme which bear on production. There should be no unknown factors of quantity outside the agreement. Thus, it is not sufficient to consider only the equipment in the relevant military formations. Up to the present, nations have had different standards with regard to stock, of which, broadly speaking, there are two kinds: first, for the maintenance of efficiency of formations during peace, and, secondly, to cover the transition from peace to war, the latter being in theory much greater than the former. It will be essential for disarmament that there should be common agreement in this matter, and again it is not sufficient to have agreement alone but conformity with general disarmament principles. The object of a disarmament scheme being to prevent the settlement of a quarrel by unhampered recourse to large-scale war, and to visualise in a very narrow way the nature of permitted hostilities should the scheme contain them, stocks must relate to the latter and be entirely inadequate for the former. It is no use, for example, submitting to drastic limitation of producing capacity and peacetime equipment within military formations, yet holding stock sufficient for very long periods of large-scale hostilities, thus neutralising all security based on manufacturing capacity, throwing the stability of the scheme back upon the difficulty of expanding combatants and abandoning any measure of security through armament limitation.

The difficulty which arises here is that some nation may consider that its agreed defensive requirements for some special reason demand great disparity of stock as compared with other nations. In a genuine attempt at disarmament this is not likely to arise, and, in any event, if there were a real case for such disparity, it would be highly inadvisable to adopt the course of standardising for all nations on this peak of individual requirement. It would be much wiser either to make some general arrangement to cover the situation, such as the creation of a central stock under general control, or, failing this, to give special treatment to any genuine special case.

To round off our discussion we have yet to consider whether limitation with the above principles in view would be effective if applied to weapons and projectiles, or whether there are some more remote elements of armament whose exclusion from the

scheme could defeat its purpose. It is difficult to generalise in answering this question, and impossible to be final until we know the range of armament which will be adopted, but, reviewing guns, tanks, machine-guns, rifles, and similar weapons, one cannot see any accessory of armament or any peacetime product sufficiently allied to armament in nature and military value to defeat disarmament either by its employment or its great facility of production. There is apparently nothing which can be put forward as being rapidly convertible into any of the major weapons or aggressive appliances.

THE TREATY OF VERSAILLES

An exceedingly important example of the partial application of these principles has been provided by the Armament, Munitions, and Materials Clauses, 164 to 172 of the Treaty of Versailles, which must be regarded as the most informed and considered opinion of the Great Powers, including the U.S.A., but presumably excluding Germany, as late as ten years ago.

These clauses are of special interest to us because they were designed, not only to prevent aggression by Germany, but for another very important purpose bearing most poignantly upon the question of general disarmament. This objective was clearly stated as a preamble to the military, naval, and air clauses of the Treaty of Peace, as follows : " In order to render possible the initiation of a general limitation of the armaments of all nations, Germany undertakes strictly to observe the Military, Naval, and Air clauses which follow," and the wider purpose was repeated with emphasis by the Allied and Associated Powers in their reply to the observations of the German Delegation on the conditions of peace. This reply was important, authoritative, final, and public, and it read as follows : " The Allied and Associated Powers wish to make it clear that their requirements in regard to German armaments were not made solely with the object of rendering it impossible for Germany to resume her policy of military aggression. They are also the first steps towards that general reduction and limitation of armaments which they seek to bring about as one of the most fruitful preventives of war, and which it will be one of the first duties of the League of Nations to promote."

It is fair to assume, and, indeed, difficult to avoid the conclusion, that the clauses in question were regarded as having bearing

on the principles and framework of that general limitation of the armaments of all nations which was to follow, and that Germany was given most clearly to understand that they were a first step to this end. A brief analysis of these clauses is therefore relevant to our subject, and very important.

They governed the reduction of German armaments in two ways inasmuch as they not only specified the quantities of specific weapons which were to be limited and retained, but they also imposed certain general restrictions which actually, if not purposely, gave effect to certain of those general principles which we are discussing. Guns, machine-guns, trench-mortars, and rifles were only permitted up to certain tabulated maximum quantities. The manufacture of any war material was limited to approved establishments or factories of known location, and all others, not only for the manufacture but even for the design of arms, were to be closed down. The Treaty did not state how the approved factories were to be related in their manufacturing capacity to the actual quantities of armament, and it would be of interest to know whether the Disarmament Commission dealt with the details of the matter with some definite principle or ratio in view.

Having thus limited the source of home production, other measures were brought into force in these clauses to make the limitation real and permanent, for the importation of war material of any kind and its manufacture for export were strictly prohibited. Having fixed the maximum authorised stocks of specified armament, all war material in excess was to be surrendered within two months, to be destroyed or rendered useless, and this applied also to any special manufacturing plant except that recognised for equipping the authorised strength of the German army. Again, having decided which types of weapons were to be allowed, the clauses did not forbid the manufacture of any other types in so many words, but imposed drastic conditions regarding certain new weapons the use of which might constitute a special danger. Thus the manufacture and importation of materials relating to chemical warfare, and of tanks and similar war engines and devices, were prohibited. The emerging of future types was not apparently regarded as a general problem.

Although we note that German armament appears to be limited to four main types—guns, machine-guns, trench-mortars, and rifles—it is not clear whether it actually was so limited. No mention was made of bombs, grenades, mines, other actual

weapons, and a host of accessories which would be regarded as part of the normal equipment of a modern army. Apart from the prohibition of gas and tanks, it was not said that the approved factories might not manufacture other weapons which were not in the authorised list. Nothing was said of gas masks, which we imagine the German army must have.

Article 166 on Stocks deals with the matter partly, but not entirely, for it said that by March 1920 the stock of munitions at the disposal of the German army was not to exceed the tabulated quantities, in which case it could only relate to the permitted types. Thereafter the German Government was forbidden to establish any other stocks, which meant by strict inference that it could not at any later time under the Treaty of Peace have in stock anything beyond the types which were listed ; but, with the exception of gas and tanks, the limitation of manufacture made no reference to armament types, and inasmuch as many items such as the gas mask, and accessories such as sound-ranging apparatus, were essential for the efficient use of the types which were listed, it would seem that we must assume the existence of categories of armament not included in the types permitted, forbidden as stock but not as manufacturing capacity, and in all probability actually being manufactured with the consent, or without the opposition, of the Allied and Associated Powers. The one conclusion bearing on disarmament which we can draw from this analysis of the clauses in question is that, although the question of permitted types of armament was left somewhat vague in the Treaty, it must have been the considered opinion of those framing it that, so long as strict limitation was applied to the four types referred to, with entire prohibition of the two others, gas and tanks, then there would be such a real check on the outbreak of hostilities that it was not necessary to pay detailed attention to other types of armament.

Any reader tempted to think that we are carrying this discussion of disarmament into non-practical, academic regions should appreciate that the structure which we have evolved regarding normal armament is simply a logical whole into which the extremely practical disarmament clauses of the Treaty of Versailles very largely fit. Indeed, if the processes in those clauses are completed and carried to their logical conclusion, making up the deficiencies as regards new types of armament and the ratio of production to equipment and stock, we reach an example of a logical and well-balanced disarmament treaty. Seeing that the action embraced by those clauses was intended, one might say

by the world, to be but a prelude to general disarmament, it would seem that the expert opinion behind disarmament in 1919, when Germany alone was submitted to it, would, if it remained consistent and was applied to the world problem, move forward very much on the lines which we have defined independently by a process of simple reasoning from known facts and first principles. Whether such a logical viewpoint will be taken when general disarmament comes forward as a practical issue remains to be seen.

CHAPTER VIII

THE NEW AGENCIES OF WAR: GENERAL CONSIDERATIONS

Armament Evolution—Its Desirability : Some Historical Data : History of the Machine-Gun : War Chemicals : General Characteristics of the New Agencies : Specific Attack *v.* Blind Force : The Argument of Limited Development : Humane or Inhumane ?

ARMAMENT EVOLUTION—ITS DESIRABILITY

Armament development is steadily going on. While planning the organisation of peace the nations are steadily developing weapons, the cumulative effect of which in two or three decades may well throw out of gear the operation of any agreed scheme of armament limitation. With the exception of timid reference to restricting chemical and bacteriological weapons there seems to be a profound silence on this subject, yet, taking a long view, the problem of the evolution of new types of armament is one of the two major issues of technical disarmament. Why has it received practically no attention ?

Studying the records of official and other organisations dealing with disarmament and allied subjects, one can only conclude that this grave matter has not been recognised as a fundamental issue. The question whether the nations should pursue the development of arms and the important issues involved have apparently not yet seized the individual, national, and international mind and conscience either at all or with sufficient force as to demand an answer. Alive as the world is to the main problem of organising for peace, yet it seems blind to one of its most important elements. If such development is indeed capable of disturbing the equilibrium of world peace organisation, then there is no better analogy than that of a surgeon performing a major internal operation and forgetting to sterilise the wound before closing it. But it is not enough to assume the simple solution that arms evolution should cease. Why is it claimed that unrestricted arms development is a danger to the stability of peace ? It might, in fact, be a danger to humanity, and undesirable, even if we admit war as a proper part of man's affairs, but that is another story.

The principles underlying this matter are very simple. Any disarmament scheme dealing with ratios of armament quantity must be based upon common knowledge and agreement as to the nature and efficiency of the different weapons. The value of so many army corps with known and agreed establishments and equipment including, say, rifles and machine-guns in one country, can be compared with similar units in another, and the agreed ratios may be determined by the military tasks which both countries have to face. With a common knowledge of the weapons involved, the stability of the position can be estimated ; but if one of these two countries develops the super-rifle, which has all the value of a machine-gun, her army corps acquire an enormously increased power, and, if this be done in secret, the stability which existed is entirely destroyed, and the carefully arranged allocation of combatants becomes meaningless. We have already examined this basic problem of disarmament in our chapter on quantity and type. The difficulty is inherent in what I have named the diverging lines of research and investigation, a special feature of the new era of arms development, and is increased by a further characteristic.

The technical history of arms reveals that the major part of such evolution before the war must be attributed to private agencies and the armament firms much more than to direct investigations by Governments. A big change of policy and procedure occurred during the war, when the State took over the initiative of development, which it did for two main reasons. In the first place the armament firms were faced with a terrific task as regards production. Broadly speaking, all their energies were required in making vast quantities of arms and components to official specifications. Research organisations which before the war were quietly evolving new and improved types of weapons to be placed attractively on the world's armament markets became absorbed in more immediate problems. Secondly, the initiative tended to come from the army, and therefore demanded action by the Government ; the main development stimulus during the war came from observation and study of enemy activities, or requirements at the front. The situation was so critical that one urgent call from the General Staff was more important than volumes of closely reasoned reports from private concerns under the conditions of peace. Broadly, in the latter the object to be attained by a new armament type arose in the imagination of the investigator, while during the war the conditions to be met had arisen, or

could be seen evolving as a change or crisis in the actual battle-zone. Instead of waiting years for a new campaign to prove and improve the design of a standard weapon, a few days or weeks of use in battle revealed defects or requirements on which quick action was imperative. Thus vast Government research organisations grew up, and the State learnt the power which it might possess by fostering them.

Now a vital and, from the viewpoint of international peace, a saving characteristic of the pre-war innovations arising from the private development and manufacture of arms was the international distribution of these developments. If France would not take the new improved Krupp model, Egypt would. If Prussia was slow in the armament market, its potential enemies were appealed to on a purely business basis. Lord Armstrong, with his breech-loading rifled built-up gun discarded by the British Government in 1863 in favour of muzzle-loaders, speedily developed business with Austria, Denmark, Spain, and other countries. There were strong international linkages amongst armament firms. Under these conditions there was relatively quick distribution of information regarding new developments. But the new situation finds a great deal of this initiative in the hands of State departments, where the utmost secrecy must prevail. I draw attention, therefore, to the fact that in the great military powers of to-day the State has largely taken over the task of arms development, particularly in regard to the newer weapons, and, in seizing an initiative which was substantially in private hands before the war, it has changed the character of that development in one important particular—national secrecy in place of international disclosure. For instance, the Maxim, a tremendous innovation at the time, was widely offered, and available for almost any country under the sun, but to-day what are the chances that a Great Power would reveal to any other country her latest discovery in poison-gas, say the nearest approach to the deadly persistent lethal chemical? True, the armament firms still seem to offer their products and new designs to former friend and foe alike, but their development scope is limited by the extent of the newer weapons which the Governments themselves still foster secretly under their own wing. Even if this were not so, the technical side has become so much more important as a decisive factor in war that it would seem there must in future be very great reluctance to allow private armament firms to disseminate their newest products, and therefore their secrets, as they did in the

past. The new policy is already in operation. Inquiries have come to British firms since the war from foreign sources to contract on profitable terms to design and supply plant and processes for the production abroad of the latest poison-gases used in the war, particularly mustard gas, and there are many cases to show that before the war this would have been regarded as a matter of simple business, when new armament could be sold as freely as new bridges or locomotives. But in the case mentioned above there was no such response; private inclinations and official sanction were against the project. Again, it was reported that assistance was given by Germany to Russia on chemical warfare production, but then only through Government organisations. There was no indication of the old system of treating such a matter as a normal commercial activity. The technical is beginning to rank with the strategical initiative in war, and to acquire its mantle of profound secrecy.

For these reasons it has become possible, in fact certain, that if armament evolution is to go on unrestricted, a few years may witness great divergence in the weapons at the disposal of the different nations. In the fields of chemical warfare we may find one country with a poison-gas which entirely evades the protective devices of the soldiers of other countries. In the development of light normal armament some infantry or one-man weapon may arise to multiply the military value of a single combatant by a factor of, say, ten, or in the field of heavy armament we may find some quick-firing device or special shell design which gives to one gun the value of many possessed by the enemy.

One such major development, or the cumulative effect of a number, might easily mean that the basis on which armament limitation was fixed became obsolete and useless, without any knowledge of the fact by the organisation whose specific object was to cope with such matters, such as the League of Nations. The development of German armament for fifty years before the war, and the new war inventions during the Great War, I submit, make it impossible for any serious person to discount the above considerations as idle dreams, eventualities so unlikely that disarmament can ignore them, and, if that be so, it is surely futile that the civilised world should remain without a positive attitude towards this subject, and refrain from exploring the avenues of possible action. There are two main questions. Are we content that arms evolution should go on undisturbed, following a course the fruits of which, by accident or design, may plunge us

into another world catastrophe? If we are so content, then there is nothing to be said, except, perhaps, the important question whether we as a nation are sufficiently active in arms development. Secondly, if we are not content, what can be done either to neutralise the influence of such growth or to prevent its occurrence? Logically these questions address themselves not only to the individual, but also to Governments.

The issue before the individual is plain. If we do not wish further generations of young manhood to fall in countless numbers before some improved form of machine-gun, is it sensible, logical, or moral that the youth of the world should take part in the evolution of that very weapon, just as though it were some harmless commodity? In short, is it fair to the individual and to humanity to leave this important matter of international policy to the mercy of chance, the motive of profit, or the guidance of the individual conscience? In answering these questions it is dangerous, illogical, and unnecessary to consider the difficulty of preventing such contributions being made and to prejudice the answer by this consideration. Any measures which could be proposed or might be taken would depend almost entirely on the force with which such questions are answered when carried through into public opinion and action. The questions must be dealt with intrinsically on their merits, and practical measures, although of the greatest importance, must be given entirely separate consideration.

Secondly, with regard to the incidence of these questions on Governments and their military advisers, the army staffs, it must be emphasised as strongly as possible that we cannot take the view that our own country alone is in the van of armament progress.

If we assume one, we must admit a number of vigorous national centres all pushing on as hard as possible under a veil of secrecy with decreasing probability of the common direction and end which characterised the past, and with certainty of great divergence of results in the future. The international wave and crest of scientific knowledge and progress would, it is true, exert a converging tendency, but this, at most, offers only feeble and uncertain security, as we can see from parallel experience in commerce and industry. In this case it is not possible to work under the same strong secrecy as will govern the field of armament; the objectives of the different organisations are much more closely allied; yet we find great divergence resulting in process and product. At the outbreak of hostilities it would no longer be possible to

make a very sane and balanced judgment as to the results of a campaign and the chances of success, for we are steadily approaching a situation when such a judgment would be a gamble, and it would be far more satisfactory for Governments and staffs, and for the people they represent, to know where they stood on type of armament, and limit their risk to a judgment on enemy capacity. They would then at least have some chance of advising on a basis of reasonable evidence, as they had in the past.

We appreciate the protest as regards curbing the path of technical progress, but most of us do not regard war as a normal activity. We cannot say that, just as it would be wrong to impede the development of healing or of transport, so for the same general reasons, and on the broadest grounds, would it be wrong to prevent the development of guns or poison-gas. For such activities as the latter, the only kind of argument which could apply, if any, would be based on expediency. A great volume of evidence has arisen since the war from the views expressed by soldiers, professional or otherwise, that the measure of pride in their activities, and of their reconciliation to war itself, is directly related to the extent to which its direct and horrible consequences can be limited to armies, and kept away from women and children. But, if one single thing is certain about unrestricted arms development, it is that it will carry this high standard and laudable objective far and away beyond the reach of military control, and compel soldiers to employ methods which react upon their fellow-creatures not in arms in a most direct and awful manner. It is true that since the war, and in isolated cases, queer views have been expressed on what is called the reformation of war, demanding—usually, we admit, in the national interest—fierce progress in the evolution of armament. We have, for example, the dedication of an important military book dealing with new and more efficient methods of war, whose brilliant author was, perhaps, carried away by professional enthusiasm :

> "To the unknown warrior in whose broken body lives the memory of a million British dead who fear not forgetfulness if through their sacrifice war may be ennobled and reformed."

The mangled body of Osborne on the German wire and of Raleigh with a broken spine entombed till Judgment in the company dugout are prototypes of that million. It is a bold, untenable, and repugnant claim that they died so that in a later war

we should employ with robot-like efficiency, with appropriate strategy, and in a properly organised army, the latest tanks, poison-gases, and other death-dealers. We need not rely on *Journey's End*, but on the cumulative force of a million fragments of personal experience, to know that those who died were not impelled to their sacrifice by their devotion to a cold military philosophy. If we must credit them with an ideal and a purpose, let us choose one consistent with the sacrifice they made, or leave them in silence.

But in these modern times the soldier and the civilian are becoming more and more but temporary classifications of the same individual ; their views are one and human. Providing the civilised world can reasonably satisfy itself that no serious evasion is occurring under a regime of restricted arms development, there seems to be only one possible conclusion consistent with a state of peace based on equilibrium of reduced armament, which is the minimum possible further development. Only two cases could arise to upset this conclusion. In the first place, if the regional scope of a restrictive arrangement were too limited, the self-imposed control of the nations concerned might place them in danger from the rest of the world, or those parts of it which were indulging in active arms development. But our whole argument is based on the assumption and need of widespread agreement, and the practical scope in view to-day, including America, Europe, and the great nations of the Far East, as it does, would leave insufficient forces outside the group to threaten its safety. In any case, if there were indications of such a threat, the alternative is not the return to unrestricted national development, but combined action.

The second possible danger is a purely theoretical one, and I only refer to it to round off my argument. The world itself as a whole might be attacked by an enemy with superior armament. This has already occurred in fiction, but the idea, although entertaining in a Wellsian romance, can hardly be allowed to have bearing on international world politics and organisation for peace. Taking a long and sensible view, can there be any question that the efforts towards peace organisation should include a strong attempt to standardise weapons and prevent the development of new types, and can it be in doubt that if those efforts ignore this matter they are simply inviting in the future the great catastrophe which it is their main object to prevent ?

SOME HISTORICAL DATA

We are going to speculate on the possibilities of the future and consider the requirements which they impose. It would perhaps be well to gather a few threads from the development of the past. In a new subject, such as the systematic study of armament or disarmament, it is very difficult to know how much can be regarded as general knowledge or requires explanation and illustration. Anyone spending many years of his working life in the evolution of technical ideas and inventions naturally acquires a comprehensive view of the process, built up from thousands of fragments of personal experience or details of study, but such experience may be quite foreign to many. To provide some background, and at the risk of introducing material well known to technical readers, may I give one or two pictures, as brief but as representative as possible, of the birth and early life of new weapons, including a reference to one which, although it can hardly be regarded as a new agency of war in the strict sense, yet has enormous possibilities?

It must be emphasised that the history of an invention, whether for war or peace, never follows a steady, easily forecasted systematic process. Here and there these characteristics apply to short stages of the whole history, but no more. It is, after all, but a concrete result of the mental behaviour of one or a series of individuals, in whose life important changes may be decided by what appear to be the most casual incidence of outside forces and events. Of this fact the history of the machine-gun provides a wonderful example.

HISTORY OF THE MACHINE-GUN

Let us at once get rid of the idea that this weapon ever arose from the conscious desire and initiative, or from any systematic action, of a Government. In the seventeenth century small arms had reached a high pitch of development. Their manufacture fed an important trade in the chief European countries, and the British gunsmiths or guilds of armourers had a world-wide reputation. A point had been reached at which the design of the weapon had absorbed the technical features and refinements which science and mechanics could at that time offer it, and the artistic impulse through metal-craft was providing the main outlet for new features of manufacture. But in the year 1663 we find

a Mr. Palmer, in a contribution to the *Transactions of the Royal Society*, turning his attention to improving the efficiency of guns and pistols. He presented to Prince Rupert, apparently his patron, an account of an invention by which one weapon could fire seven shots "to make a pistol shooting as fast as it could be and yet to be stopped at pleasure, and wherein the motion of the fire and bullet within was made to charge the piece with powder and bullet, to prime it and to open the cock." This is the first trace of the automatic principle of firing which finally led to the evolution of the machine-gun. It is true that the idea of firing more shots from one weapon in a given period of time arose still earlier, in the orgues, or organ guns, of the fifteenth and sixteenth centuries, but these did not embody the principle of making the discharge perform the work of preparation for the next shot. The organ gun was simply a sort of composite musket, with anything up to ten barrels on a frame, usually with one lock firing a quick match, which connected with the various barrels, but it passed through various phases of development, and appeared in the defence of Charleston Fort in the American Civil War in a somewhat improved form. Thus we see the machine-gun emerging along two main lines of development, through crude attempts at an automatic mechanism in a pistol or rifle, and from the heavier weapon, the organ gun. From the early part of the nineteenth century right up to 1862, when the first name clearly associated with machine-guns emerged, i.e. that of Dr. Gatling, there were suggestions and patents on the automatic principle.

Dr. Gatling was an inventor in Chicago. It is not clear why he turned his attention to armament, unless it is that the American Civil War provided a motive, through his devotion to one of the parties or the possibility of rapid profit. His gun consisted of a series of water-cooled barrels built round a central axis. As they rotated, the separate barrels were fed with ammunition, and to this extent of automatic feed it departed from the organ gun, its ancient prototype. It is again clear, as in most of the cases of new armament types which we mention, that he, the inventor, was far in advance of the official armament mentality of his country and time. It was not a question of a Government, war department, or official specialist taking the lead. This is a particularly good example of a constantly recurring situation in the evolution of armament; the military were blind to the possibilities of the invention, even in face of the crying needs of the war in which they were engaged. The Gatling Gun Company failed to place its

guns with the combatants by the usual process of negotiation and demonstration, and it is recorded that in their zeal they sent out crews of employees with Gatling guns who actually demonstrated the weapon by taking part in the fighting. This is no criticism of Dr. Gatling or his company, but it is an interesting fact that an armament inventor and firm should have gone so far as to risk the lives of their employees, even though they may have volunteered, in demonstrating their wares by actual experiment on living soldiers in battle. It shows clearly what I have frequently pointed out—that civilisation has not yet developed a background or an attitude towards armament development able to give reasonable guidance to the individual, and to remove him from the influence of a more or less haphazard or undirected impulse when faced with possible action in the direction of new weapons. In the usual way the Gatling was offered indiscriminately to various Governments, and in 1869 an English technical committee sat upon it and bought guns for tests. It was also sold to Turkey, Egypt, Tunis, China, Japan, and Morocco, but the biggest customer was Russia, who bought four hundred Gatlings in 1871. They became known as "Gorloffs," owing to the fact that Count Gorloff negotiated the purchase in America on behalf of the Russian Government, and his name was used as a mark on the guns supplied.

About the same time in Europe we find another important link in the chain of machine-gun development. A Belgian officer, Captain Faschamps, about the year 1850 evolved a machine-gun which he offered to Montigny, an engineer and compatriot interested in arms manufacture. The gun was produced and offered to Napoleon III, but they had the very greatest difficulty in persuading him to adopt it. Although facts about the gun were generally known in armament circles, including Germany, which which was soon to be engaged in a war with France, the latter surrounded the Montigny gun, or mitrailleuse, with a veil of the greatest secrecy. This led to such ignorance of possibilities, tactics, and use in the French army that, broadly speaking, the gun was a failure, and retarded other Governments and War Ministries from taking up machine-guns for periods up to ten years. The main error, a natural one at the time, was to regard the machine-gun as alternative to a field gun, and to employ them side by side in artillery units, the result being that, owing to the shorter range of the machine-gun, it was knocked out of action, being unable to silence the opposing artillery. Meantime, the well-known

name of Hotchkiss arose in the machine-gun field. He was an American engineer living in France, and developed a gun on the same principle as the Gatling, but of a larger calibre, so that it fired a small explosive shell. The later forms of Hotchkiss used so widely by France and other countries were small-calibre machine-guns more on the lines of the later Maxim. Then a Swedish inventor, co-operating on the commerical side with a banker and compatriot named Nordenfelt, who later became a famous armament magnate, developed a gun of the organ type, as did Gardner, an Englishman, and both were employed to a certain extent in European armies.

But the great impulse to machine-gun development, and particularly its use, was derived from Maxim. Broadly speaking, it is true to say that until he came on the scene machine-guns were all operated by a lever or handle which controlled the series of loading, firing, ejecting, and reloading. They had none of them taken advantage of the principle suggested by Palmer in the seventeenth century, which would enable the gun, once it was started, to go on firing so long as the feed was maintained, not requiring the continuous operation and attention of the operator so far as feed was concerned. Maxim was a well-known inventor, and visited Europe about the year 1880 as an agent of an American electrical company. He was interested in many things, but at that time was mainly concerned with electric lighting, which, although in its infancy, was beginning to acquire importance. He had had no connection with armament production in his training and business, and the casual and indirect way in which he came into this field, where he made such vital contributions, cannot be shown better than by his own words : He says, " In 1881 I visited the Electrical Exhibition in Paris and was made a Chevalier of the Legion of Honour on account of some electrical and chemical work that I had done ; and about a year later I was in Vienna, where I met an American Jew whom I had known in the States. He said, 'Hang your chemistry and electricity.' If you wish to make a pile of money, invent something which will enable these Europeans to cut each other's throats with greater facility.' This made me think of the time when I was only about fourteen years of age, and was making drawings for my father of a hand-worked machine-gun. I also thought of the powerful kick I got the first time I fired a U.S. military rifle. On my return to Paris I made a very highly finished drawing of an automatic rifle. Happening to meet a Scotchman in Paris whom I had known

in the States, I showed him my drawings. He invited me to come to London. I did so, and shortly after I started an experimental shop at 57*d* Hatton Garden.

"As soon as I had ascertained that a gun could be made that would load and fire itself from energy derived from the recoil, I took out a series of patents. I made and patented guns worked by the backward motion of the cartridge in the chamber at the instant of firing, by the force of the gases escaping from the muzzle, and by pistons worked by the high-pressure gas in the barrel itself. In fact, I patented every conceivable way that a firearm could be worked by energy derived from the burning powder. All automatic guns, therefore, are Maxim guns ; nothing new has been evolved since I finished my experimental work at Hatton Garden.

"As soon as my gun had been perfected, I was asked to fire before the British officials at Enfield. They asked for a gun that did not weigh over one hundred pounds, that would fire four hundred rounds in one minute, and six hundred rounds in two minutes. I made a gun that weighed about fifty pounds and fired two thousand rounds in three minutes with one pull of the trigger. None of the recent so-called inventors have ever been able to equal this.

"The automatic system has come to stay. Two-thirds of all the Japanese killed in their war with Russia was due to the Maxim gun, and at the present time the greatest military authorities in the world tell us that the Maxim gun is fast supplanting infantry fire." (Letter to the editor of the London *Star*, July 23rd, 1915.)

The chief characteristic of Maxim's gun was the fact that it was a substantial success from the moment it was designed and constructed. This is unusual in armament history. The whole design was clever and an attribute to Maxim, and the chief new features were that the gun continued to fire itself from the energy of recoil of the barrel, which, through a sequence of operations, governed the feed of a cartridge which arrived on a belt instead of, as in the past, employing a gravity or hopper feed. Almost from the start he was able to get six hundred bullets per minute from one barrel. The gun attracted the greatest interest of certain military investigators in England, and was shown at the Inventions Exhibition at South Kensington in 1885. Demonstrations were made to the War Office and others, and manufacture was commenced at Messrs. Vickers, Crayford, near London. Maxim travelled Europe demonstrating his gun with a view to sales.

The Kaiser, seeing it in Berlin, told Maxim, "This is the only machine-gun," although practically every other type had been brought to his notice. He exerted his personal influence to get the active interest of his military staffs, and it is again a very interesting point that, in spite of the unique influence of the Kaiser, the German staffs hesitated for some years before adopting the Maxim. Although when the Great War broke out they had some fifty thousand, far more than any other country, there is very little sign that official Germany would have reached that position but for the enthusiastic work of the private inventor. The comment of Li Hung Chang, the famous Chinaman, when he saw the gun at Crayford, is amusing and instructive. For his benefit the trunk of a thick tree was severed by machine-gun bullets, so that the tree fell, but when told that the cartridge expenditure of the gun, operated at such a speed, was about thirty pounds per minute, he said this was far too expensive for China. The later history forms an important chapter in the story of the private armament industry. Zaharoff attended Maxim's demonstration in Vienna as the Nordenfelt agent, realised his own gun as a thing of the past, that the future lay with the Maxim, and by a series of business moves, whose cleverness we must admire, brought about the fusion with the Nordenfelt Gun and Ammunition Company, in which the Maxim interests figured at over one million pounds. Then came further expansion by amalgamation with Vickers, and the gun as firmly established in the international armament world as was the mysterious star of Zaharoff in its firmament. Sales increased, and with the Great War the Maxim gun reached the peak of a swift crescendo of profit, mutilation, and death which can hardly be equalled by any other individual weapon.

Broadly speaking, and ignoring the extraordinary nicety and cleverness of certain features of design which arose later, there were two chief innovations after Maxim's gun. The gas-engine type was evolved in which a valve in the barrel allowed gas under pressure to escape into a chamber while the barrel was still itself under pressure from the discharge. This controlled release of pressure operated the automatic feed, instead of the recoil, as in the case of the Maxim. The later Hotchkiss was an example of this type. Secondly, great improvement has been made in the light air-cooled machine-gun, the most successful example of which is probably the Lewis gun. All the details of the evolution of this weapon are of the greatest interest, but we have no time to enlarge on them. It is, however, a fair and a very important conclusion

that, although we find the world's armies employing hundreds of thousands of machine-guns and causing millions of casualties with them in the Great War, there is no single Government which was in the early stages at all keen on the weapon, there was no real official impetus towards its development and use, and, had there been a definite policy regarding the evolution of arms, it is quite likely that this deadly weapon would never have arisen.

I cannot resist contrasting the mild seeking of a remote scientist of the Stuart period for new fields of ingenuity, leading to the automatic principle, the casual comment of an American Jew in Vienna, the starting of an inventive thread in the mind of Hiram Maxim, the drawing made and the idea dormant waiting for the accidental advent and commercial impulse of a Scotchman to blossom into manufacture, with the horrible results of the fruits of these chance stimuli clearly focused in the following account from an eye-witness of the shambles at Thiepval.

"It was then, turning back, that I knew what the novelists mean by a 'stricken field.' The western and southern slopes of the village had been comparatively little shelled ; that is, a little grass had still room to grow between the shell-holes. The slope was held by tangle after tangle of rusty barbed wire in irregular lines. But among the wire lay rows of khaki figures, as they had fallen to the machine-guns on the crest, thick as the sleepers in the Green Park on a summer Sunday evening. The simile leapt to my mind at once of flies on a fly-paper. I did not know then that twice in the fortnight before our flank attack had a division been hurled at that wire-encircled hill, and twice had it withered away before the hidden machine-guns. The flies were buzzing obscenely over the damp earth ; morbid scarlet poppies grew scantily along the white chalk mounds ; the air thick and heavy with rank, pungent explosives and the sickly stench of corruption." (Extract from *A Subaltern's War*, by Charles Edmonds.)

Meantime the process goes on, and there could be no better example of our casual attitude towards it, and blindness to the issues which are being created by it, than the announcement to-day of the firing trials by armament makers of the new self-loading rifle invented by Colonel Pedersen of the U.S.A. I forecasted many months ago, when drafting these pages, the line of evolution of the machine-gun under circumstances of unrestricted development, showing how the aim would be to combine the death-dealing capacity of the machine-gun with the ease of handling of the modern rifle. Colonel Pedersen's ingenious gun represents

the first small step in working towards this armament ideal. The description has appeared in *The Times* of Tuesday, February 25th, 1930, and in many other prominent journals, almost without comment. The new rifle apparently resembles the standard Lee Enfield, but does not appear to be heavier, although it involves a special self-loading and ejecting mechanism. This is operated by the recoil, which ejects the empty shell and replaces it with a cartridge from the clip. The latter contains ten cartridges, but the capacity may shortly be increased to twenty. In keeping with our forecasts, the rifle has a somewhat smaller bore, and consequently a lighter cartridge than the standard. The bullet is stream-lined, and weighs about twenty per cent. less than the old type. The muzzle velocity is somewhat higher than the standard. As the new rifle eliminates the very tiring bolt action of the past, and all the physical movements of control other than trigger pressure and the loading of the second highly charged clip, it is anticipated that a speed of bullet discharge can be attained, two or three times as high as during the war, with no increase in fatigue—in fact, with a considerably decreased demand on physical endurance in long-continued firing. This, of course, only gives us an expectation of from thirty to forty bullets per minute as against many hundreds by the standard machine-gun, but it is the beginning of a new impulse in machine-gun or rifle evolution which cannot fail to lead to far more striking and deadly possibilities.

WAR CHEMICALS

War chemicals of the poison-gas type cannot provide such a long and interesting armament history. Certain of them were born as chemical individuals more than a hundred years ago, but only during the last few years have they acquired an interest as weapons. Mustard gas, for example, was first made known to the world in 1854 by the chemist Richie, in working up new series of organic chemical compounds and adding to the structure of organic chemical theory. Then Guthrie in 1860 examined and described the properties of the substance chemically known as dichlorethylsulphide, and he recognised its peculiar and powerful physiological properties, but in no way imagined the military applications. Again, in 1886, Victor Meyer, the famous German chemist, made small quantities of the substance in his laboratory, and examined it from the purely chemical and physical point of

view. These chemists, in preparing the substance for examination, naturally worked out processes which were employed later for manufacture in the Great War. This new chemical individual, having played its part in the development of the science, was more or less forgotten for many years. Now and again we find reference to it in the chemical literature, and, although the physiological effects are recorded, no comment whatsoever is made regarding military applications. Professor Bayer, in the year 1887, working in the University laboratory at Munich, commented on certain organic chemicals as possessing possibilities for war through their lachrymatory or blinding effects, but this was not the case with mustard gas, and even as late as 1913, when my friend, Dr. Thacker Clark, working with the renowned German chemist, Fischer, had occasion again thoroughly to explore the mustard gas chemical, it was with a purely chemical objective. Dr. Clark was simply examining the physical properties and relationships of certain classes of organic chemicals containing sulphur.

The military use developed only after the Great War broke out and the general question of poison-gases had become important by the introduction of chlorine on the front. Then at once we find powerful Government organisations collaborating with Universities and similar institutions in Germany, Italy, France, England, and later America, in an effort to give mustard gas its maximum value as a weapon. It is interesting to realise that the war possibilities of mustard gas remained dormant for fifty years, but Hiram Maxim's gun, speaking broadly, was quickly applied to war. Why was this ? The reason is obvious. The Maxim gun was a direct contribution to a known form of armament, whereas modern chemical warfare was unknown. There was then no receptivity of attitude towards poison-gas in the military staffs and departments ; but now there is, and unless something is done we may expect the same quick uptake, or quicker, with an important new war chemical.

Indeed, this is well illustrated by the birth of the famous war chemical Lewisite, known also as methyl and "The Dew of Death," which is worthy of examination as a typical example of the thought and research process which may characterise the future development of the new agencies of war. In 1917 war had added to its armoury the powerful agent mustard gas, which was a novel type owing to its new direction of attack upon the human organism through its powerful vesicant properties.

With the arrival of such a new agent one of the first ideas which

strikes the investigator is whether any peculiarity of its chemical composition is responsible for, or related to, its casualty-producing and physiological properties. We shall see in our discussion of the argument of limited development that such a relationship does not always emerge, but nevertheless its examination is one of the important possible methods of scientific procedure which cannot be ignored. Now the general chemical characteristic of mustard gas, or dichlorethylsulphide, was its formation from ethylene and sulphur dichloride and its corresponding structure. These two chemicals were both members of classes of similar compounds. Ethylene was an unsaturated hydrocarbon, and sulphur chloride was an inorganic non-metallic halogen salt. The non-chemical reader should not avoid the argument because the names are strange. One does not n ed to be technical to appreciate that other combinations from members of these two classes might yield the same physiological and war-valuable effects. The first approach to the problem was to substitute for ethylene some of the other members of the same class or family of chemical compounds—the unsaturated hydrocarbons. Butylene, a neighbouring member, was at once tested with sulphur chloride. There were special reasons for this. Butylene has a higher molecular weight, density, and boiling point, and might have yielded a mustard gas sharing these properties and possessing thereby tactical differences and advantages. Further, ethylene was manufactured from ethyl alcohol, a substance already employed in large quantities for other war products, and it would have eased the supply situation if butyl alcohol could have been employed, should its derivative butylene give a good war agent with sulphur chloride. But the butyl mustard gas turned out to be much less active, in no way capable of replacing the dichlorethylsulphide, and was not employed.

But a large number of other similar avenues were open for investigation—in fact all the combinations of the two classes of unsaturated hydrocarbons and non-metallic chlorides—and in research W. Lee Lewis, an American officer and chemist, succeeded in combining acetylene with arsenic chloride, obtaining chlorvinyl dichlorarsine and allied compounds. It was this or a mixture which was termed Lewisite, and its characteristics have still further bearing on our argument. It approached mustard gas in its vesicant or skin blistering and destroying powers, but possessed other casualty-producing features, although, as it was not employed on the front, the evidence in support of them does

not take the form of the overwhelming number of casualties which illustrate the mustard gas effects. There are not masses of gruesome war medical photographs showing the hardly recognisable human bodies of Lewisite victims. However, the product was thoroughly investigated in the U.S.A. by very competent organisations, and we have no reason to doubt the claims, which were as follows. Apart from the vesicant action, it seemed to have more deep-seated effects—a capacity to penetrate the skin and carry the chemical attack farther into the system. Three small drops on the abdomen of a rat caused death in an hour or two. It was a very powerful respiratory irritant, and thus shared some of the aggressive value of phosgene and chlorpicrin.

The results of introducing complex organic arsenic compounds deep into the human organism have not been very thoroughly investigated, but they might be extremely unpleasant, far-reaching, and even fatal. The possibilities are sufficiently described in the *Official History of the War*, in the section dealing with war diseases, to refute any suggestion of exaggeration. There the effects of the milder organic arsenic compounds, largely employed by the Germans under the name Blue Cross, are analysed, and we need only make passing reference to the standard and main tactical influence of these compounds—violent sensory irritation in amazingly low concentrations. The symptoms, the report states, are quite characteristic : intense pain in the upper respiratory channels, nose, throat, and chest, inflammation of the eyes, vomiting, and great mental depression and misery. Positive effects are noted in a few minutes in concentrations of one part of diphenyl-chlorarsine in two hundred millions of air. At one in fifty millions the average limit of human tolerance is five minutes. One in ten million will probably incapacitate a man within a minute from pain and distress, and two or three minutes bring nausea and vomiting, the effects increasing in severity even after leaving the poisonous atmosphere. Sometimes a comatose or lethargic condition exists for twenty-four hours. Curious mental states may develop, and men may act as though driven mad. A case is recorded of an organic arsenic casualty having to be forcibly restrained from shooting himself. Alterations in motor power appeared, and men lost the power of limbs, being temporarily paralysed ; parties would struggle on to dressing-stations with frequent falls and apparent loss of mental control. Fortunately recovery was fairly rapid.

How far these effects are due to absorption is not clear, but

it is significant that men, by using water, say, from shell-holes, contaminated with organic arsenical substances, showed many of these symptoms. Amongst others the case is cited of six men of the Oxford and Bucks Light Infantry who infused tea drawn from a sand-bag left by the previous occupants of a gas-shelled trench. The water was apparently from an untainted source. One did not drink the tea and was unharmed, but the other five soon showed the usual symptoms in varying degrees : acute pain, lachrymation, vomiting, and loss of use of limbs or speech. If, as has been suggested by medical experts, some of these effects are due to absorption and resultant nervous disorders, we see the bearing of Lewisite, an agent possessing two very important tactical and casualty-producing effects in a high degree, with the new possibility of deeper application of new organic arsenic compounds whose specific effects have yet to be explored. The possible combinations of the two types of chemicals which produced mustard gas and Lewisite are very great. The number of metallic and non-metallic chlorides is limited, but the unsaturated hydrocarbons are very numerous, and their derivatives, which could also be employed in this reaction, are almost countless. Who can say what possibilities even this narrow field of war chemical investigation may contain? It has been very fruitful up to the present, perhaps more so than we are generally aware.

The discussion which follows must be read with this kind of historical data in mind.

GENERAL CHARACTERISTICS OF THE NEW AGENCIES

We cannot assume that considerations which apply to disarmament in the field of the older, and so-called normal, armament can be carried over entirely, without separate consideration, to the control of the new weapons. This fact has been generally recognised. When President Harding called the Washington Conference, and summarised the subjects with which it would deal, one of them, in a class by itself, was the new agencies of war. As a matter of fact, they did not, at that conference, receive a fraction of the attention which their position on the agenda demanded, but their specific importance and place in a disarmament scheme was clearly implied. What are the new agencies of war? At any given time armament is divisible into two classes, consisting, first, of those forms which have already matured as accepted weapons, and, secondly, those which still remain in a

state of partial development, or hidden in the future, undiscovered, inherent in the scientific and industrial progress of years to come. Naturally, not all such progress and development in weapons or war appliances comes under the category of the new agencies. There are many armament improvements, marvels of scientific and technical ingenuity, which contribute only to the greater precision and more rapid and efficient use of normal weapons. The cumulative effect of such developments during the war was great, but their importance for the future pales before an entirely new weapon such as chemical warfare.

The simplest distinction possessed by a new agency of war is one of principle, i.e. it introduces some entirely new method of aggression, and may be an entirely new form of casualty producer, either in the type of wound or the method of producing it. Let us analyse for a moment what we actually do when we cause a casualty, a wound, or death. Up to 1914 a casualty was the result of the incidence of violent force on man, so that by penetration of his body with lumps of metal, or by injury to his organs or limbs through metal or high explosives, he became one of two things—an inefficient or dead soldier. The first change introduced into war by chemicals was to multiply, thousands of times over, the force at the disposal of prechemical wars, i.e. the force of man himself, alone or assisted by simple mechanical devices such as the flight of an arrow from a bow. This change occurred when explosives were introduced. But during the Great War a new type of aggressive chemical developed which was an even greater advance upon the explosive, and, some would say, reduced it to a secondary position. The explosive merely remained the means of projecting the new chemical a sufficient distance to surprise and envelop the enemy troops. This new type of chemical made a less violent and more insidious attack on the special organism and functions of man. Thus, chlorine and phosgene liberated from a shell or from a cylinder and wafted along on a gentle breeze were able, by mere contact with man's respiratory system, to produce the same effect, as far as war was concerned, as the old-fashioned explosive. Mustard gas attacked an entirely different part of the human mechanism, but was equally gentle in its approach, and equally insidious in its results. The future chemicals of war, if they are allowed to develop, will be still more specific, increasingly effective, and capable of still finer adjustment to the evasion of the protection of the modern soldier.

SPECIFIC ATTACK VERSUS BLIND FORCE

In general, instead of the clumsy and wasteful use of enormous quantities of energy released by the explosion of relatively big quantities of explosive chemicals, the new chemical warfare employs much smaller quantities, but much more specific and potent types of energy. This is produced by chemical reactions between the so-called poison-gases and specially chosen parts of the body. We have, for example, the reaction between chlorine, phosgene, and lung tissue and the respiratory membranes, or between mustard gas and the outer skin of man. By reaction I refer to the whole range of harmful effects which are produced. As compared with explosives, the amount of energy actually employed in producing the casualty is infinitesimal, even when we take into account the high proportion of the gas which envelops, but does not actually attain, the soldier. One small mustard gas shell can liberate enough gas to cause casualties on an area from ten to twenty yards in width, to many hundreds of yards in length, according to the wind velocity. An obstacle, such as would spend the force of a high explosive, has little meaning to mustard gas. Minute fractions of an ounce held up by the clothing, hands, or face of a soldier will make him a casualty, but the remainder of the atomised liquid will carry on with its deadly work, capable of influencing a great number of men in a large area. But high explosive of a weight considerably greater than that of the mustard gas, falling in the same area, will have a very limited range of action, and may, indeed, and often does, spend its force harmlessly. How well we remember little groups of men, say working-parties, pressing home along communication trenches towards the relative comfort and rest of distant billets, suspected or observed by the enemy and " sniped " with heavy shell. Often the enemy gunner would follow such a group for a long distance, making great craters a few yards from the parapet, but with no more damage than slight wounds from masses of falling earth, stones, or splinters. Then the poison-gas contrast ; a few gas shells spreading their heavy fumes in a wide valley, turning back and incapacitating reinforcements and ration-parties, postal motor-cyclists, and compelling wide detours. With the old type of chemical weapon it is a question of hit or miss, even with shrapnel, but with the newer chemical weapon it is not a question of a few fragments of metal, or a local region of pressure, but of the enveloping effect over great distances of millions of effective particles

of atomised liquid or vapour. Briefly, we have the specific use of minute quantities of chemical energy in a subtle, enveloping form, as against the extremely local, clumsy, and wasteful use of vast quantities of explosive force. The new chemical persistently seeks out its objective, while the old one is blind, once its point of impact is determined.

We have never yet been faced with an absolutely decisive weapon, but if the persistent lethal compound arises, as it may well do, it will fit the formula. The great feature of the new type of chemical attack is the possibility of its surprise influence on a hitherto attainable and unprotected human function. How is it that other sciences have not produced similar effects? To this there is no general answer. Consider electrical science for a moment. It is more than eighty years since Faraday made those fundamental discoveries which introduced us to new phenomena which might well have been thought ultimately to find a decisive use for war. Yet, although this result has often been prophesied, it has never materialised. High tension and other forms of electricity are capable of producing very violent effects on man—such effects as might well be of great and decisive value in war, if they could be applied. This is the crux of the whole situation, the application of the new idea. The generation of the kind of electricity required to cause casualties involves, at the present stage of scientific and industrial development, such plant as renders it impossible rapidly and unexpectedly to convey the deadly force to the opposing soldier. To use high tension electricity in aggressive warfare, armies would have to transport huge appliances and bring the enemy to them. This is a farcical conception. It is reasonably safe to say that modern electrical science contains no ground for any forecast that harmful electrical effects will soon be available for wide use in war, but perhaps any such forecast is hazardous. Chemical science introduced great improvements in propellants and explosives during the Great War, but they were not of the same order of importance, and fall into an entirely different class from the introduction of poison-gas or chemical warfare. The new agents contain inherent in their application, and increasingly in their future development, the power to convey the decisive war initiative to those nations capable of exploiting them on a large scale. Chemistry seems to dominate the position at the moment, but a long view cannot exclude other sciences from the field of newer agencies of war.

THE ARGUMENT OF LIMITED DEVELOPMENT

Chemists, physiologists, and others have at times expressed the view "that it is improbable that toxic agents of much greater destructive power than those hitherto experienced will be discovered."[1] The comforting nature of this argument is naturally a great temptation to accept it. But if it were generally accepted as a basis of action or inaction, and later proved to be wrong, it would be difficult to overestimate the harm it could do. I must, therefore, be allowed to digress a little and examine it in detail, particularly as advocates of other new weapons may later on think fit to adopt the argument, and some of our discussion has general bearing.

Early in 1923 a number of scientists, mainly chemists and physiologists of various nationalities, were asked to report to the League on chemical warfare. I can trace in their reports practically no reference to chemical disarmament, but mainly statements on the properties and effects of war chemicals, with comments on protection. These reports throw light upon the argument of limited development.[2]

Senator Paterno, of Italy, unquestionably one of her most famous chemists, partially supported the argument. He said: "The assumption that with perseverance new substances of greater military value than any yet known can be discovered and manufactured on a large scale has no basis, although, of course, it cannot be entirely ignored.

"Thus, to say that at the beginning of the war about thirty asphyxiating gases were known, whereas to-day there are more than a thousand, is an entirely valueless argument, seeing that this rapid increase from thirty to one thousand does not include any recently discovered substances, and that phosgene, chloride of cyanogen, and Yperite, which occupy the foremost place among the thirty, still occupy the same place among the one thousand. The obvious conclusion to be drawn from this fact is that the fresh researches carried out on the one thousand substances have proved fruitless."

Senator Paterno would have been the first to admit that some of these conclusions admitted amplification. It could at least be advanced that Lewisite, a most important new war chemical,

[1] *Armaments: Their Reduction and Limitation*, L. of N.U., p. 21.

[2] L. of N., CTS/Experts/4.

was a recently discovered substance. Again, no one really knows the results of the fresh researches in the various countries. True, the increase from thirty to one thousand is misleading, as he says, but it must be remembered that the extra nine hundred and seventy substances were not absolutely new compounds in the chemical field, but mainly the result of a search for known compounds with toxic properties, the latter having been largely ignored in the researches which gave birth to these substances in the past, for the obvious reason that such properties were far removed from the object of the investigation. We do not expect chemical science to produce new war chemicals at the rate of several hundred per annum, but we cannot possibly admit the improbability of any such developments, for reasons which will soon emerge.

Professor J. B. S. Haldane tends to support the case for limited development, but, as his able summary also exposes some of the weaknesses of the position, I reproduce it below :

" We have seen that a case can be made out for gas as a weapon on humanitarian grounds,[1] based on the very small proportion of killed to casualities from gas in the war, and especially during its last year. Against this may be urged the probability that future research will produce other gases or smokes which, as weapons, will be as cruel as, or more cruel than, the chlorine and phosgene used in 1915 and 1916. The answer to this is quite simple. First, as regards gases or vapours. Only a limited number of chemical substances are appreciably volatile, and of their vapours only a small proportion are poisonous. Now every chemical substance has a definite molecular weight. Those with a small molecular weight, i.e. whose molecules are relatively light, are on the whole the most volatile, i.e. go most easily into vapour. Now the large majority of the possible volatile chemical substances of small molecular weight, and therefore relatively simple chemical composition, are already known. Mustard gas, for example, was discovered and its properties described in 1886. There are probably substances of high molecular weight whose dense vapours are even more poisonous than mustard gas. But the charcoal of our respirators has the property of absorbing heavy molecules of vapour quite independently of their chemical composition. It is, therefore, somewhat unlikely, though not, of course, impossible, that any very poisonous vapour will ever be found which can go through a mask impermeable to mustard gas or chlorine. It is, to my mind,

[1] See p. 192, " Humane or Inhumane ? "

far more probable that skin irritants may be discovered which are even more unpleasant than mustard gas.

"The question of smokes is more serious. It was the hope of the producers of irritant smokes that they would penetrate the gas-masks in sufficient amounts to cause sneezing and force their victims to remove their masks, thus exposing themselves to greater concentrations of smoke and to poisonous vapours liberated along with the smoke. This was the German view when they introduced the Blue Cross shell in July, 1917. Fortunately, by that time our defence against gas and smoke was extremely good, and we had foreseen the smoke menace and introduced, between April and June 1917, a filter which effectively stopped it in the concentrations then met in the field. It is not, however, at all unlikely that concentrations of smoke will be produced in the future which will penetrate our present masks. If our anti-gas measures are sufficiently neglected, the consequences may, of course, be very serious."[1]

Professor André Mayer, the renowned professor of the Collège de France, who has made almost a life-study of the specific effects obtainable upon the human organism by variations in the chemical molecule, in pure and medical science as well as in chemical warfare during the war, emphatically expresses an opposite opinion, saying, "The recent war produced a new weapon which may lead to a revolution in warfare comparable to the revolution caused in the past by the use of explosive. This weapon is the chemical weapon. It is doubtful whether the peoples of the world are aware of the power of this weapon and the danger which threatens them." "Chemical weapons are thus capable of producing the most various physiological effects. Their power, their efficiency, and their diversity are as unlimited as those of pharmacology or any branch of chemistry. The wide range of artificial colouring matters is an example of what can be done by chemistry when it is desired to vary the compounds in order to obtain every possible shade, and thus to produce the most complex impressions on an organ of the senses."[2]

There are thus diverging opinions upon this important question amongst these eminent scientists, but I think a sound line can be taken, first, on the basis of simple reasoning, and, secondly, on technical grounds. First, no well-informed scientist would dare to come forward and maintain that development of new chemical warfare types was impossible. The maximum claim is

[1] *Callinicus*, pp. 38, 39, 40, and 41. [2] L. of N., CTA/Experts/1.

that it is a difficult matter, with few avenues of approach, not capable of yielding quick results. Although we do not actually agree with this view, let us accept it for the moment and draw the logical conclusion so făr as disarmament is concerned. This is a question of safeguards. The results to be checked, should they emerge to disprove the arguments of limited development, would be so terrible that the safeguards could only be neglected by a sane people if it were unanimously agreed that under no circumstances could any such development occur. Where the possibility of armament development exists, there disarmament demands a check or safeguard irrespective as to whether that development many remain unborn for long periods.

On technical grounds we can only be guided by two main standards: are there any guiding scientific principles which would enable us to conclude that no further such chemicals could emerge from research? And, secondly, what is the general experience of parallel fields of investigation? With regard to a guiding scientific principle, it will be seen above that Professor Haldane was thinking in that direction when he referred to the fact that the number of volatile chemical individuals, usually of low molecular weight, was limited, and we can therefore more or less visualise whether the field had been covered or not. Now, whatever the value of this argument—and it is, in fact, not quite watertight—it has no final bearing on the question of limited development, because there is no reason to believe that it is only the volatile organic chemicals which can produce the war chemicals, as Professor Haldane himself points out. Therefore we again ask, In the field of organic chemicals of high molecular weight, relatively non-volatile substances, is there no guiding principle? Now the one branch of chemical and physiological science which might have assisted us in answering this question would have been the one to which Professor Mayer refers above, i.e. the study of the relationship between chemical composition and physiological properties. To make this clear I would mention one or two simple illustrations. Chemical substances can be grouped into families in which the members or individual substances are all different, but related, diverging from one another in a definite way, so that the parent molecules or compositions are common to all. Now in such a series of chemical compounds it is a fact that very often the physical properties vary in a definite way with the gradation of composition. Thus, for example, in a given series the boiling-point or optical properties of liquids may vary uniformly, with

very few exceptions. But when we come to physiological properties the ground is very much more doubtful. A number of scientists have spent much time in endeavouring to show relationships between chemical composition and physiological properties, but, speaking very broadly, although they do now and again show relatively short series of compounds with increasing or decreasing physiological activity in a definite direction, yet the thing which emerges most strikingly is that quite suddenly in a given series the physiological effect will change. For instance, mustard gas is a member of a very clearly defined family of compounds many of which have been identified and examined physiologically, some of them are more accessible commercially than mustard gas itself, and it was hoped therefore that they would prove to have the same dangerous properties, during the war, as their brother substance, mustard gas. Unfortunately, or fortunately, whatever the viewpoint, the scientific law did not apply, and in one case, the butyl compound, a slight change in the molecule, although it gave a substance more readily available, because it depended in manufacture upon less restricted raw materials, yet made it relatively useless for war. In other words, we have not yet reached the position in which we can predict with certainty how slight variations in chemical composition will govern the physiological and therefore the war-valuable properties of a chemical.

Now when we consider the enormous number of different types of organic chemicals, and when we realise how existing harmful chemicals emerge from a narrower, but still very wide, range of families, we can see that there are great possibilities of variation in war properties which no one could predict. In other words, on purely scientific grounds it is impossible to establish any argument of limited development, and the case of the latest generally known war chemical, Lewisite, fails to support it.

The second standard to which we referred was that of experience in similar fields. For instance, there was, and is, and must be in the future, great activity on pharmaceutical chemicals, and a great volume of scientific literature has surrounded the subject of the relationship between the chemical composition and the particular medical property under investigation. In this way soporifics, narcotics, anæsthetics, and all kinds of valuable medical classes of products have been investigated. Not only is this of importance to the pure researcher, but if any valid rule could emerge it would be of the utmost commercial value to the manufacturer. Surveying this field, series after series of organic

chemicals can be taken, and one finds, for example, that four or five members of any given series have a very mild physiological effect in a certain direction, and then suddenly, with no apparent rhyme or reason, one member of the group stands out as being extraordinarily active, and finds medical and commercial outlet. Naturally, at some time or other, science will no doubt resolve all these differences, and show how they are related to some fundamental property, which has probably not yet been sufficiently studied to reveal its bearing. But the only permissible generalisation is that, although we are looking for rules and relationships, the exception is almost as big as, if not bigger than, the rule, and, in other words, moving from medical war-valuable properties, it is quite impossible to predict limited development, and equally certain in the other direction that if work is done results will emerge.

If the issue were simply academic, and we were merely toying with the fate of a minor theory, the risk could be taken. We could agree together that development of new chemical types was so unlikely that we could forget it. But what if an error means the fate of a generation of manhood, or even of mankind ? Can we then take a chance ? Can we then allow unlimited development, ignore all measure of control, on the strength of a probability that nothing serious will emerge ? If modern medicine would not tolerate such a risk in the treatment of a single body and saving of a single life, how can modern civilisation gamble with ten million ?

HUMANE OR INHUMANE ?

We saw how the argument of limited development of new chemical weapons, true within certain very narrow premises, tended to allay alarm regarding chemical warfare, but to impede the full official exploration of disarmament in that field. The same tendencies appear in the numerous references made by prominent scientists to the less brutal nature of chemical warfare as compared with other weapons. But this is only one aspect of a much wider question. Can the development of new types of armament be viewed with equanimity and ignored in the organisation of peace on the grounds that they will follow a less brutal course and lead to less horrible results than in the past ? I can see no signs anywhere in armament, its history, its present tendencies, its scientific roots, or in the reaction of man towards it, for anything but a most disquieting answer.

Within certain very narrow limits, the argument for the less brutal nature of poison-gas is no doubt true. One starts with the fact that over the whole period of the war the mortality or the death-rate in relation to casualties was lower for gas than for the other weapons amongst the Allies. But the argument usually stops there, and the situation requires both a closer analysis and an extension of the premises to make the conclusion applicable or otherwise to the dangers and needs of the future. By far the greater number of gas casualties occurred during the later stages of the war, when the Germans were using vast quantities of mustard gas, whose well-known vesicant or skin attack did not tend towards fatal results, and mortality rates were in the region of two per cent. to three per cent. But mustard gas as used up to the end of the war was not grouped by the official medical services and physiologists with the true lethal or killing agents. Had the war continued, it might have moved into the lethal class, for both sides were straining every effort in cunning ways to give to mustard gas certain characteristics which would undoubtedly have increased the fatal nature of its casualties. Attempts were being made to change the point of attack from the unprotected outer skin to the highly sensitive respiratory membranes, either by admixture with arsenical and similar chemicals, which would compel the removal of the mask, or by giving mustard gas that peculiar particulate nature against which the mask at that time afforded less protection.

But this is not the whole story, as we can see by considering the early German cloud attacks, which were characterised by the use of acute lung irritants such as phosgene, or phosgene mixtures, against troops possessing at first no form of protection, and later only the more primitive type of mask. Thus we find the German cloud attacks between December 1915 and August 1916 yielding an average death-rate of twenty-four per cent., rising as high as forty-six per cent. in one particular attack—on August 8th, 1916. Then the cloud arrived during divisional reliefs in congested trenches—a very similar condition, incidentally, to gas from the air falling on panic-stricken civilians in town streets, with a very good chance of still higher mortality in the absence, possibly, of gas-mask protection, and certainly of gas discipline. Again, the danger of generalisation as to low mortality is seen from the use of the same chemical types by us against the Germans in our projector attacks at a later stage of the war, when German protective devices were highly advanced. We find in some cases

the astounding mortality of over sixty per cent. In June 1918 the British discharged about nine hundred drums of phosgene into the village of Ablainzeville, near Arras. The German official report tells us that the troops were disciplined, and had received warning of a probable gas discharge. The Germans had conducted a destructive bombardment upon the sunken road which was supposed to harbour the camouflaged projector batteries, dug-outs had carefully been given the usual blanket protection, and generally gas discipline was good and masks were adjusted soon after the gas warning sounded. In spite of this, experienced officers and men were gassed. Only a few died at once, and many marched back with their companies soon after the attack, before reporting the sickness which in a very high number of cases took a fatal course following the characteristic delayed action of phosgene.

The position is clear. We cannot generalise about a process or growth such as the development of chemical warfare by limiting our facts and evidence to one small phase of that process. We are therefore compelled to fall back on more general considerations, and ask whether science affords any substantial grounds for the conclusion that armament development is likely to follow a less brutal course. How could there be any such grounds? The brutality or otherwise of a weapon is not related in any narrow way to the scientific principles underlying its development, for the kind of physical reaction which it will have on man is quite incidental. Take a case in point. If we pursue the machine-gun to its logical conclusion, applying to it the next fifty years of metallurgical and mechanical progress, it is easy to forecast a weapon of much lighter weight, with a much greater rate of bullet-discharge, in which weapon and projectile may well be built up of new metal alloys. Purely technical considerations will govern the nature of these alloys, but it will be found that they either produce a more merciful or a more terrible wound. Their effects may produce a condition of maximum sterility, simplifying the medical problem, or of intense inorganic poisoning, producing unknown horrors. These considerations are quite incidental to the guiding principles in the development of the most efficient weapon, and, if they come in at all, will do so, not on scientific grounds of cold armament efficiency, but because man has introduced a new ethical factor in such developments, compelling him, sometimes against technical standards, to modify the weapon in the direction of lower brutality.

This introduces the final question, which really governs the

ethical possibilities of armament development. Are there solid grounds to reassure us that automatically, without any further action on our part, the evolution of weapons will follow a consciously directed course towards more humane results? In making a sane judgment on this point we can only admit the evidence of the past. We cannot assume some suddenly introduced and new attitude towards weapons. The evidence of the past gives no support to the claims of a definite halting by man before the growing brutality of his weapons. There have been slight pauses, when he was dimly conscious of the end towards which armament evolution was forging, but the issues of the moment, the supposed advantages over an adversary, have always swamped any broader motive which might have diverted the armament race. The steps in chemical progress, black powder, nitroglycerin, dynamite, modern H.E., chemical warfare during the Great War, and even now in peace, are evidence enough. It must be abundantly clear that if we want to stabilise peace through disarmament, then in contemplating the new agencies of war we shall be in a fool's paradise if we neglect any practicable measure in that direction because of the suspicion, or even the claim, that the wolf may evolve into a lamb.

CHAPTER IX

THE NEW AGENCIES OF WAR: WEAPONS AND SCIENCES

New Physical Agents : The Chemical Contribution : " Disperse " Types : New War Poisons : Piercing Poisons : Bacteriology and War : The League Reports

The development of new armament types, new forms of weapons, and the new agencies of war, is unquestionably a matter of fundamental importance in the theoretical structure of disarmament. This point has been established in our discussions on " quantity and type," and in other places, and could hardly be challenged. Is it of great practical importance? The last chapter exposed and discussed certain reassuring suggestions which have come forward with authority, implying, although not openly drawing the conclusion, that it is not. They hint that, although the facts surrounding the problem seem to be very alarming, yet in effect the new agencies of war tend to neutralise their own dangers through some inherent tendency of limited, or in any case humane, development.

We have seen that the facts and arguments brought forward in support of such views were decidedly flimsy and inconclusive. They revealed nothing which could be relied upon to stem or even retard the fierce torrent of armament development which is at this moment raging and gaining in volume. But we require a positive and more constructive view. It is not enough to re-establish the atmosphere of alarm and emotion which has surrounded this subject up to the present, which alone and unsupported is almost as dangerous as apathy. We want a sane and scientific view of the direction likely to be taken, and the volume which may be assumed by this stream of armament progress to gauge the results which it may achieve and the havoc it may play in human destiny.

The birth of new forms of armament and weapons, like all scientific discoveries, must occur in the sciences themselves. They will arise, naturally, out of peacetime scientific work, or from the deliberate and concentrated pursuit of science as applied

to war. If we want to estimate the future of power development for transport in a serious manner we do not make a series of wild guesses, but are content to be guided by the present trends and future tendencies of the underlying sciences relating to combustion, new forms of energy development, and engineering design. To probe the future of the paint industry we do not draw solely upon our imagination, but we look at the new raw materials which are coming forward, the new types of natural oils, the new fields of synthetic chemistry which could lead to new binders, the trend of development of synthetic dyestuffs and pigments, and a host of other factors which any serious paint manufacturer must consider in moving forward.

In other words, the problem of peering into the future of some form of applied science is not new, and the development of armament can only be visualised by the same methods to produce results of practical value for the organisation of peace or war. In other words, we must go back to the individual sciences from which new weapons could emerge, and which would foster their development. There we shall find certain facts and definite trends which must to a certain extent govern what might occur in the future.

How far have the different sciences contributed, or are they likely to contribute, to the new agencies of war which may arise now and in the future? I must reiterate that in disarmament considerations we absolutely cannot cater for all time, and must take a reasonable, practical view of the near and middle future—say the next two or three decades. It is more than probable that under a disarmament scheme fair warning would be given of basic scientific changes in armament in the general trend of scientific and industrial development, as in normal industry, so that any measures in operation could be suitably modified, assuming that changes arose which were sufficiently important to demand modification. The first fact which strikes one is that the only new casualty producers, the real aggressive agents which have developed since the Middle Ages, are chemicals. Let those who think that the importance and the need for control of chemical warfare has been exaggerated ponder this point. Other branches have contributed towards improving, and have, in fact, revolutionised certain weapons. But chemical science is the only one which has introduced new casualty producers. If chemicals were now to be so controlled that they could not be used for war, or if their use were adequately limited, then hostilities would be

reduced to mediæval proportions. The great scientific progress of which we are so proud, the numerous inventions which have revolutionised warfare—in fact, the total of scientific development at the present time, if we eliminate chemical science—has not made a single contribution to the direct production of casualties !

The reader may at once ask, " What of the tank, the aeroplane, and the submarine ? " But a little thought will show that the tank loses the greater part of its unique value in the absence of chemicals. In the first place, as an aggressive agent it would be limited to the transport of troops, but the only means of aggression would be those of the Middle Ages. It might be used as a Juggernaut. Its formidable protective devices would be pointless in the absence of chemicals—that is to say, in the absence of explosives, or propellants. If you have no propellants to impart enormous velocity to machine-gun bullets, and to the different kinds of shell, you need no protection against those velocities. If you have no high explosives, or even mild explosives, you need no protection against them. More than that, it is doubtful whether you need the enormous and complicated trench system which developed during the recent war. If these do not have to be overcome, the value of the type of progression of the tank, i.e. the caterpillar system, becomes much less. It is extremely doubtful whether, in a non-chemical war, the tank is an efficient agent. Its duties could be taken up by much lighter, swifter, more economical, and equally efficient means of transport. The aeroplane, examined in the same light as an aggressive weapon, loses most of its value without chemicals, and its main value is limited to reconnaissance, the rapid transport of men and stores in special cases, and as an agent of propaganda in enemy countries. It is difficult to visualise aeroplanes dropping cannon-balls.

Why has chemical science made such a contribution to war ? There are several reasons which depend on certain peculiarities of chemical science. I have already shown above how, in terms of energy considerations, recent additions to the chemical armoury can be explained, and future additions, if the matter be uncontrolled, are to be expected.

If we visualise some malignant power surveying the whole of science with a view to devising methods of exterminating humanity, and follow its probable train of thought, it should lead to a conclusion as to which of the sciences is able and liable to make the maximum contribution. Such an enemy of mankind might take one of two viewpoints. He might examine in what scientific field

the most drastic results could eventually be obtained, disregarding the time factor, or which science is likely to make the maximum contribution in what I call the near and middle future—say the next few decades. It is the answer to the latter question which should be of maximum interest to those considering disarmament, but let us deal with both.

One could classify the destructive possibilities of science very broadly under two heads, i.e. physical and chemical developments. Physical developments would include the possibility of harnessing destructive forces, new forms of energy, or new ways of conveying old forms. All the older weapons come under the physical heading. It is true that the past has brought forward spasmodic suggestions and attempts to cause casualties by chemical rather than mechanical effects, such as the use of boiling oil, molten lead, poisoned arrows, or even Lord Dundonald's suggestion to employ sulphur dioxide in the Crimea, but in magnitude these have been museum specimens of war-making. The club, spear, bow and arrow, boomerang, catapult, and the diverse members of the same family, all aimed at penetrating, disrupting, or breaking up the human body by mechanical force, and they all had a more or less individual application or attack. The development of explosives represented a considerable step scientifically, but actually, as regards the formation of the casualty, it was again the application of violent force, highly magnified, to cause the same effect. The one difference, of course, with high explosives and shrapnel was to widen the objective, which was no longer individual, but a group or zone. There may be possibilities of developing more powerful chemical explosives, but the development is limited. After all, the actual effect is due as much, if not more, to the impact of flying metal fragments, broken shell, rather than with the actual gaseous blast. We are concerned with the rapid expansion of a small volume of solid explosive into a great volume of gas, and it is a field in which an enormous amount of investigation has been done since the beginning of modern chemistry. Here it would be true to say that practically all the possible chemical types have been visualised and even examined, and, although one anticipates refinements, it is not likely to occur that some new chemical will provide an explosive blast so much greater in effect as to constitute a new weapon.

NEW PHYSICAL AGENTS

On the other hand, there has been much speculation as to whether entirely new physical agents might be used as weapons. A good deal of study has been devoted to the use of high tension electricity, but the maximum result has been of quite a modest nature, such as the use along wire entanglements outside fortified bases or more permanent field defences. The real possibilities lie in the application of some newer and more subtle force, such as is termed in popular literature a " ray."

We have, for example, relatively violent effects produced on the body by radium emanation. The question at once arises in connection with war, Could the availability, the precision, the intensity, the range, and the scope of such an effect be so developed as to become a weapon? Modern physical science is only beginning to examine the forces which come into play in the internal structure of the atom. Science has for very long periods examined the different forms of matter, the various elements and compounds, and, by assuming the existence of the so-called ultimate particles, the atoms and molecules, has been able to build up a rational system by which it could interpret and even forecast the behaviour of matter. By assuming and deducing the characteristics of such ultimate particles, scientific systems had been built up which have given man the marvellous control of materials which he now has. But this is only the beginning, and a new world has been exposed by the revelation of the intra-atomic forces, i.e. the forces and energy within the atom, which it is now thought is itself simply a vast system of smaller units, the nature of which is only slowly emerging from the region of speculation. The early work of Sir William Ramsay and others, however, did reveal that matter and atoms were not the unchanging and fixed things which had been supposed, and were capable of evolving into other forms, and, in doing so, producing effects which could only be interpreted in terms of the action of very powerful forces and big energy changes. The physical and physiological effects of radium which gave the world its first popular contact with this matter were but the beginning of a new science which is revealing the vast stores of energy within the atom. Through radium and other of the rare elements we are faced with such changes going on unsuspected, only waiting to be identified, measured, and classified, but the great question which has arisen is whether such changes can be stimulated and controlled, whether by some combination of existing

forces which can be handled by man the element can be made to split up and make available for use its concentrated force and energy. If this could be done, and if we could control and use intensively the changes which nature has shown us occur slowly in the case of radium, we should enter an entirely new phase of applied science, which would revolutionise industry and could also revolutionise war.

Numbers of eminent scientists have been asked whether such a thing is possible, and they always reply that it is so, but on fewer occasions they have been asked what is the nature of the development process, and how long is it likely to take, and then they could only argue from previous experience in the development of entirely new branches of science. There development has from the general point of view been very slow, sometimes a hundred years from the first researches to any extensive application by mankind. It is not likely that any new weapons will emerge from these developments for very long periods, even if the most intensive and extensive investigations were carried out, and such results for war can be postponed almost indefinitely, if not entirely eliminated, by taking a sane view at this early stage. On this so-called physical side of science we cannot look with certainty for quick results in the form of new weapons.

It is very interesting to speculate on the type of thing which might emerge if these possibilities became practical and were applied to war. So far the physiological effects of the various rays and emanations are relatively crude. We get the destruction of human tissue and the inhibition of that combination of factors which renew it. We are trying to get the specific destruction of harmful tissue for remedial purposes ; it is in the development of specific effects that medical progress in this matter lies, and there is no reason to believe that the effects of such forces, if developed, would remain in this crude and indiscriminate form. When we visualise the human body we realise that there are all kinds of vital parts and processes which are, to a certain extent, physically and chemically distinct the one from the other, and which should in theory be susceptible to different forms of energy influence and attack. The nerve circuit, for example, represents, according to some physiological chemists, not only a mechanical unit, but a series of different and delicately adjusted elements, many of which are of a very sensitive chemical nature. There is some scientific justification for regarding the nerve circuit as an electrical or electro-chemical conducting element, containing

along its length a large number of units which function as electro-chemical cells, with all the characteristics of the latter, such as their sensibility to specific chemicals or poisons, to their concentrations, and to variations of type and load of electric force passing along the circuit. In all parts of the human organism physiological and physical chemistry are revealing structures, membranes, and regions which function or behave in a similar manner to purely chemical or lifeless systems. Of course, the whole subject is immensely complicated, and no cell or element which could be reproduced in the laboratory would really represent its nearest parallel in the body, for it would be an infinitely crude representation. But at the same time we have the following broad conception—that such systems or structures reproduced by chemical and physical means in laboratories are susceptible to changes by the incidence of various forms of energy, ranging from the oldest known forms, such as heat, through the later discovered electrical forms, to the most newly discovered types related to the intra-atomic forces.

Now it is possible to visualise transmission of specific forms of energy from machines to the human body, i.e. to soldiers, with the result of specific effects on that body, producing casualties. If we can destroy tissue and prevent its growth by the application of such forces at short distances, it is permissible to speculate that in the future, which may be very distant, this phase of applied science could be so highly developed as to produce these effects over much greater distances, with much more perfect machines and more specific results. For instance, it has become known in recent times that chemical changes or chemical reactions can be produced or influenced by electrical vibrations. Even gaseous mixtures of relatively inert gases, which would remain practically unchanged for very long periods, can be stimulated to react and produce valuable commercial chemicals by passing through the system very high frequency electrical waves. The creation of this electrical zone is to-day a matter of such relative cost and difficulty that technical industry has not yet largely employed these processes, and it may be many years before this position is reached, but the new phenomenon is established. The point is that, given very long periods of time and intensive investigation, the problem of influencing a delicately adjusted chemical system in the human body by newer forms of energy is not far removed from the above example. A great deal of work would have to be done, but who would care to forecast that scientific development could never produce such results?

The use of sub-atomic energy is already the talk of engineers speculating upon the sources of power of the future, and Professor Eddington's 1930 lecture to the World Power Conference gives a glimpse of the new vista of science, upon whose war potentialities we are ourselves speculating. Sub-atomic energy is, and may for long be, a question of very dim facts, with slowly growing objective, or experimental support, and no one to-day could draw positive conclusions. It seems clear that the quantities of energy involved are fabulous, for a drop of water contains sufficient to maintain a flow of two hundred horse power for a year—enough, say, to drive a touring car at twenty-five miles per hour continuously for twenty years. As fuel, if machines and control could be developed this drop would be equivalent to the use of one hundred and twenty thousand gallons of petrol in the internal combustion engine of a modern motor-car.

But, even with the great commercial incentive for the use of such a reservoir of power for industry, we have not proceeded far beyond an idea of quantities involved. Professor Eddington says, "This land of El Dorado, this paradise of power; the energy of which I am speaking exists abundantly in everything that we see and handle. Only it is so securely locked away that, for all the good it can do us, it might as well be in the remotest star—unless we can find the key to the lock. The cupboard is locked, but we are irresistibly drawn to peep through the keyhole like boys who know where the jam is kept."

The two great problems are the release and the control, and on the former science is only beginning to give vague indications, coupled with grave warnings on the latter. Various considerations, including the energy equilibrium of the stars, suggest that sub-atomic energy would break its atomic limits, and that the matter or substance concerned would disintegrate, if it could be raised to a temperature of forty million degrees. Professor Eddington tells us: "At the Cavendish Laboratory, Dr. Kapitza produces momentary magnetic fields in which the concentration of energy corresponds to about one million degrees. If he should be able to raise this to forty million—well, I have said that I do not think that the sub-atomic energy will then come pouring out; but, just to be on the safe side, I shall take care not to be too near the laboratory when the experiment is first tried."

We thus have the established fact of the slow release of this type of energy from radio-active substances, which already finds therapeutic use, and a more or less general agreement that this is

simply evidence of an enormous reservoir of energy which, although we can identify its leakages and use them, we cannot tap in bulk. To the best of my knowledge no one has cared to speculate on how such forces could be used for war, even if we could release and control them. Power and war have their own problems of application. We imagine that efforts would be directed towards beam effects, to produce destructive and physiological effects or casualties at a distance. It may be that the solution of the problem of releasing such energy from ordinary forms of matter will be found in the direction of some stimulus or catalytic effect, which could be made specific as regards distance, or accumulative in time, or preferential and capable of seeking out definite chemical forms of matter. All such properties and phenomena would have war application somewhat after the fashion of the "ray" of popular literature. Infected disintegrating zones or military obstacles would thus be possible, and we would have a new range of sub-atomic tactics.

Of course, this is the vaguest form of speculation, and we do not rely on it in any way whatsoever to support the importance of the simpler new agencies of war. On the other hand, it should be pointed out that the relationship and the time interval between modern physics and the realisation of these possibilities may be no more than those which we have seen between the primitive beginnings of chemistry in the Middle Ages and the use of complex organic chemicals in the Great War.

In any case, it seems that new physical agencies for the production of casualties are likely to be related to such new phenomena, and are therefore possibilities of a very distant future. It is unlikely that time will prove us wrong if we ignore these matters in our practical consideration of disarmament.

THE CHEMICAL CONTRIBUTION

But on the chemical side it is another story. We are not dealing with a field in which masses of fundamental investigation have to be carried out. The science has a swift and efficient technique to ring the changes of new chemical combinations. The chemical weapon cannot be considered by itself, but must be thought of in relation to the effect it is going to produce on man. Chemical warfare has so far revealed relatively few vulnerable points, such as the respiratory system, the eyes, and the outer skin, but there

must be inherent in chemical science many new possible combinations of attack by special chemicals on specific functions or organs. The possibilities are bound to emerge from the further development of medical science itself.

To claim that a very thorough survey of all known chemicals has been made with a view to their use as weapons without any substantial results apart from those which are already employed does not get to the heart of the matter. Chemical science has still a lot of work to do in perfecting the known poison-gases if they are to be pursued and not abandoned. We know the broad conclusion which emerged as a result of war experience—that, although we had a number of very dangerous and deadly substances, there was a big gap between their efficiency in testing stations and in the field. The reader is not dependent on the writer's opinion in this matter, because the known activities of the different chemical powers towards the end of the war prove that they were striving to bridge this gap, and they fully realised that it existed. That very deadly substance, phosgene, for example, was somewhat disappointing as a casualty producer because of its inherent tendency to dissipate, due to the physical and chemical properties of the phosgene molecule. It rapidly lost mass concentration, and was disintegrated by chemical attack under ordinary atmospheric conditions. The later forms of the German Livens projector bomb show quite clearly that German chemists were fully alive to this point, and were working to overcome it. They were only using simple physical methods of doing this, based on the high absorptive properties of chemical liquids of relatively low boiling-point, but there are other and probably much more efficient methods of reaching the same end. We could multiply examples, but will not do so, because they are too suggestive as to future work in this matter.

Again, the use of war chemicals was only in its infancy during the war as judged by another practical technical standard. The need of quick results compelled the war chemical departments to concentrate on the most obvious vulnerable points of man, i.e. his respiratory channels and his skin. Broadly speaking, the actual reactions which caused casualties and death were primarily surface effects, although, of course, the secondary effects were more profound and deep-rooted. But if we consider the control which medical science has on specific functions of the human organism by the careful injection of very small quantities of complex organic chemicals, we realise that a whole field of active

chemicals was excluded from war use for the simple reason that their activity depends on an internal application which was beyond the powers of existing chemical weapons. But that need not remain so—witness our comments on Lewisite; and one can visualise many combinations in which the older war chemical, or modifications of it, is no longer the main aggressor, but simply becomes a carrier for more subtle physiological agents.

Post-war chemical developments provide no indication of a thorough exploration of a limited zone of possibilities, but reveal a steady growth of new forms emerging from the old. There is, however, a much wider field of speculation, full of possible developments, which is intensely practical, although it deals with the future. Right through history, in private and political quarrels, the art of the poisoner has figured in removing enemies, and humanity has always regarded this method with particular horror. The attitude has never changed ; it is as strong to-day as ever in the past. Until 1914 the abhorrence of the poisoner was felt, not only in private, but also in national quarrels. Crude attempts to use poisons or chemical methods in war were suggested on occasions in the past, and sharply rejected by those nations within whom they originated.

We can say bluntly and without hesitation that in this field the attitude towards poisoning seems to have changed. Chemical warfare is nothing less than poison warfare. We do not say that for this reason it is any more terrible and to be deplored than other methods of killing. At the same time, we must realise that the poison war has not been violently rejected ; it may have been reluctantly admitted, but it has come, and, unless something is done, it will undoubtedly develop.

The future of chemical warfare, therefore, takes shape as the development of mass poisoning, and from this point of view we can speculate with some assurance on the possibilities before us.

"DISPERSE" TYPES

All the chemicals used up to the present have been enveloping types, governed and limited by their nature as gases, vapours, or smokes. Physically we have used what can be called " disperse " systems, and these have been thrust upon us, with their limitations, owing to the fact that practically no work had been done on methods of carrying the chemical to the casualty. We therefore

had to use the simplest possible forms, such as cylinders or projectors, and avail ourselves of old methods, such as shell.

These methods did not allow the chemical to be directed to a definite individual human objective, but compelled us to surround a number of possible objectives in the hope of attaining the maximum number of casualties. Thus the rifle projected its bullet to one definite opposing soldier, whereas the gas shell created a zone of gas, and was ignorant, so to speak, of the casualties which it might eventually attain. This condition was decided for us, as I have said, by the disperse nature of the chemical and the essential dependence upon old or rapidly improvised forms of chemical weapon.

NEW WAR POISONS

But as soon as these limitations are removed there arises in theory, and there may well appear in future war, a new form of mass chemical poisoning, not dependent upon a limited range of chemicals, which can be used in the disperse phase. If any nation had started out to develop the poison war in peace, with long periods of secret and quiet development, unhampered by immediate hostilities, it would have sought inspiration in various directions, which it was not practicable to follow in the Great War. The poison art of the Borgias, and other classical exponents, would have been examined; the possibilities of emulating the intense poisons of the animal world would have been explored, and assistance would have been sought in the medical field, where traces of special chemicals exert the most powerful and specific effects upon the human being in the cause of healing.

Such a nation would have argued, and rightly, that this objective was incidental, and if these powerful agencies could be found for healing they could even more easily be uncovered for destroying. In such fields there is a very wide range of extremely active compounds, often fatal when introduced into the human body in extremely small quantities, and not yet exploited for war. Modern fiction has by no means exaggerated the possibilities in this direction, and we need only mention the deadly snake poisons, the complex alkaloids, or the latest anæsthetics, the latter often fatal if used in more than the very small quantities and dilute concentrations which medical science permits.

There is, indeed, a vast field in which future search can be made for chemicals with intense and specific harmful effects upon the human organism. The moment we admit, as we must, that long periods of work in this field towards the medical objective will produce results, so we are compelled to take the view that if we substitute the very closely allied military objective the search may be equally fruitful. It is the technical similarity, the common scientific background, and not the moral opposite, which will govern the solution of the problem.

Can such products be applied to war at present? That we do not know, but we do know that they cannot be applied by the methods which were used in the last war. The problem of the future, then, is not only one of new chemicals, but of their new methods of application. Are such methods likely to emerge? Arguing from the Great War, we are bound to answer this question in the affirmative, for the past chapters have given some indication of the great flexibility of methods and variety of results when science concentrates upon armament. But we must go beyond generalisation and consider some practical possibilities.

PIERCING POISONS

A broad characteristic of these newer chemical effects is the much more deeply rooted introduction of the poison into the body than was possible with the disperse systems, the gases, vapours, and smokes of the past. These came gently into contact with the outer surface and membranes of the body, which are physically resistant. They found difficulty in penetrating, and even a corrosive substance like mustard gas spent its force and largely limited its results in attacking and destroying the outer membrane. There is probably no case on record in which phosgene or chlorine as gas or vapour produced casualties by skin attack. When such gases entered the respiratory channel they were again attacking outer membranes, but special types, which are in closer and more intimate connection with the deeper-rooted chemical and physiological systems such as the blood, through such organs as the lungs. In such cases the effects were more profound, but the approach and contact had the superficial characteristics of disperse types in general. Even in the case of hydrocyanic acid, widely used by the French armies under the name Vincennite, the sharp and deadly

reaction on the nervous system occurred indirectly by absorption after breathing.

We can get the contrast with the new type of piercing poison by considering the powerful organic anæsthetics such as stovaine. Some readers may have experienced the removal of an appendix under the influence of this chemical, which, injected into the body at certain places, produces total loss of feeling and control over wide regions. The medical use of stovaine depended entirely upon its injection into special parts of the body closely related to the nerve systems to be neutralised, but carefully chosen to prevent the access or substantial distribution of the drug over the whole organism. Failure in this respect might mean death. We can imagine the results of the introduction of such a substance into a soldier, rendering him as helpless as a log, at the complete mercy of his enemies, or killing him outright. The difference between the medical and the military purpose with the same chemical would decide between life and death. The military objective would be to introduce the product in such a way as to produce the maximum damage, and the care taken to avoid this in medical work is sufficient evidence of the ease of reaching it. Stovaine may be a poor example ; there may be reasons why its introduction into the body by the violent methods of war would tend to neutralise its results ; but there are no reasons which would apply in general to all such substances.

The intense care taken to introduce the first small doses of snake poison in the treatment of epilepsy again shows that the controlled use of such substances is not a fairy-tale, but simply a part of general scientific progress, and it is evidence of the dangers for war. Our argument does not depend upon some isolated case such as this, but it might be said that the greatest possibilities for war were likely to be found amongst these extremely active animal and vegetable poisons, and it might therefore be objected that because they are usually of a very complex nature, in many cases unidentified, their wide use was an impossibility. The implication would be that one could not turn the medical supply of a few kilogrammes into the war needs of many tons.

But modern scientific trends would not allow such a conclusion. The nature of these extremely complex substances with intense and specific properties is very gradually being disclosed, and their production is correspondingly being brought nearer to a practical possibility. Perhaps the greatest headway in this field of science has been made in connection with the vitamins, on account of the

great medical and commercial impulse towards their control and production. These substances defeat attempts to identify them by the same methods and with the same ease as would apply to a new chemical which possessed definite crystallographic form or relatively simple constitution. But methods are being worked out to define the conditions under which such substances retain their identity and remain active, and practical use, apart from scientific progress, depends more upon this than upon scientific knowledge of their exact composition. The same type of argument again applies that, if in the allied field of the vitamins, upon which a concentrated attack is being made, practical results can be forecast, then there is no reason why the same conclusion should not apply to the war application of allied products.

But it is extremely unlikely that the piercing poisons of the future available for war would be limited to such complex types. Just as medicine is seeking for specifics in synthetic organic chemistry, and particularly, at the moment, in the metallo-organic compounds, so war may seek in the same field. Unsuspected active substances of very simple nature are continually cropping up. We find, for example, that a new substance, lead tetra-ethyl, has remarkable properties in motor fuel performance, and we then uncover the fact that it is a deadly poison, and the utmost precaution has to be taken in limiting concentrations and handling the product in practical use. There is no point in examining the whole field in detail, but it would be futile to argue that the future does not hold these very real possibilities.

It is gruesome and repugnant to visualise the possibilities, but the moment we seriously consider disarmament we must face the fact that poisoning has entered the field of weapons. Poisoning has come forward in war in a manner which suggests to mankind that somehow there is a real distinction between that form which has always revolted us and chemical warfare as used to date. There is no real distinction, and the fact that we have employed disperse systems, novel gas cloud effects, atomisation, and smokes, simply involves a tactical distinction, but not one of principle.

There are one or two obvious ways in which these developments might occur with the deeper-rooted, or what we may call the piercing, poisons. They must be taken deep into the body to produce their effect. There are weapons available for the purpose. The problem is to convey small quantities of certain chemicals deep into individual human objectives in such a way as to release the chemical with the maximum chance of entering or contacting

with the particular system of the body on which it exerts its deadly physiological effect. The machine-gun, with its hail of bullets, would serve admirably for the purpose if the appropriate bullet could be developed. What are the difficulties ? The bullet is raised to a certain temperature after projection. The chemical must withstand or be protected from the heat effect. This is not an insoluble physical or chemical problem. There are ways of raising the temperature of decomposition of heat-susceptible organic chemicals, and there are physical means of neutralising the heat effect on the poison-container or chamber in the bullet. The armament problem is simply that of a special chemical bullet, perhaps more difficult than the other special bullets which were developed, such as the incendiary and the visible bullets, but by no means insoluble.

Tactically there would be two types : slow acting, as, for example, some of the organic arsenic compounds, and almost instantaneous, like some known animal poisons. The use of the rifle and the machine-gun up to the present has been to produce the maximum number of immediate casualties, but, even though the chemical were not immediate in its action, it would still be accompanied by the usual effects of violence of the projectile. If we regard the mortality of those attained by the machine-gun in the past war as below fifteen per cent., as was claimed, it is quite clear that the poison bullet, even though the effects were delayed, would increase that mortality to somewhere between fifty per cent. and one hundred per cent. Even in the last war there was a sporting chance in infantry attack against machine-guns—a very lean chance, but definite. In many attacks very few were not hit, but many survived. But this would all be changed. The problems of the poison-container within the bullet, heat effects, design of bullet, and every scientific obstacle between the past absence and the future employment of this new weapon, could undoubtedly be solved, and there are a number of men in each of the chief former enemy and Allied countries who could undertake to do it, were they so inclined and supported by national policy.

I will not enlarge on these possibilities, as they might become too suggestive. The point is that, the moment we visualise movement from the disperse type of war chemical to the piercing poisons we see chemical warfare invading the whole field of new and normal armament, it absorbs or becomes accessory to the use of all forms of small arms and of artillery, and no longer remains a bounded isolated problem of disarmament, but, as the chief

casualty-producer, becomes the chief weapon to be considered.

The poisoned bullet or small projectile would almost certainly produce the well-known dum-dum effect. Instead of a clean wound from a bullet, which more often than not retains its original shape, it would be essential for the mechanism to break or shatter the chemical container, with the inevitable ragged wound, which, indeed, would be necessary for the most efficient action of the chemical. It would be curious, and an interesting side-light on human nature, if the repugnance towards, and the refusal to use, the dum-dum bullet were abandoned and lost sight of because that effect was an essential accompaniment of the chemical bullet.

For some reason there has always been a repugnance in military circles to employ the shattering type of projectile such as the dum-dum. It seems to have been regarded as the last word in the horrors of war, which must be guarded against at all costs, and so strong has the feeling been that such projectiles have been substantially absent from modern wars. We are, of course, only too sadly aware of the awful wounds produced by this type of weapon, but at the same time it is very difficult to see why such a wide distinction is made between this isolated case of a new agency of war, and the other far more substantial and important ones which arose during the war, and have been fostered since, which are infinitely more important in relation to the whole problem of armament and disarmament, and in the long run have far greater bearing on the fate of the common run of individuals who provide the cannon fodder.

Should armament development break down the artificial boundary which has been formed between the use of poisons in a disperse phase and those which in the past have been associated with the poisoner, it is difficult to exaggerate the effects which might be produced. A solution on the lines of the above discussion would mean that mortality from bullet wounds would increase from the region of three per cent. to perhaps eighty per cent. The chances of a "blighty" wound would be enormously reduced, and it would be regarded as almost certain death in an attack to be touched by such a bullet. There is no doubt that the logical and unimpeded development of chemical warfare means a general movement from the mechanical to the chemical type of casualty, and the reviled art of the poisoner would either become generalised in war, or by it lifted out of the reach of the censure of mankind. Technically this evolution means movement from the use of disperse gaseous chemical systems to the employment of very small

quantities of solids or liquids, adding the rifle and the machine-gun to the chemical armoury, and thus making all the major forms of armament a means of expression of chemical warfare or mass poisoning.

Indeed, the moment we assume the possibility of these new casualty-producers the nature of future chemical wars takes shape with some degree of certainty. The old chemical types are particularly suited to civilian objectives, such as great centres of population. The increasing mechanisation of war, the greater mobility of troops and normal armament, will lessen the importance of cloud attack and its later forms, which were most suited to trench warfare. Their place will undoubtedly be taken in actual battle by the newer chemical casualty-producers employed by the normal forms of armament as piercing poisons, and the enveloping types will be taken over by aircraft use for the mass killing of civilians.

Such considerations simply compel us to the reluctant conclusion that chemical warfare is the one new agency of war which possesses more immediate development possibilities than any other.

BACTERIOLOGY AND WAR

The subject of "Weapons and Sciences" would not be complete without reference to the bacteriological weapon. Ever since it was discovered that certain diseases were associated with the presence of minute organisms such as bacteria in the diseased body, and that these organisms could be transferred from one body to another by various methods, it has been possible in theory to apply to war this method of producing casualties. There are records in the annals of crime showing that man has employed bacteria in private warfare, but it is exceedingly doubtful whether such methods have ever been employed in organised war. There were rumours towards the end of the Great War that in the fighting areas, and behind them, some of the belligerents had projected bacteria on to the enemy by various methods, but they were probably no more than rumours. There are all kinds of difficulties and objections with regard to the use of this form of attack facing anyone who would propose to employ it. The simplest and most obvious difficulty, which has been referred to on numerous occasions, is the spreading of the contagion beyond the limits of the enemy into the forces and peoples of the user. This difficulty can, of course, be answered in theory by suggesting

that the forces using such a weapon would be rendered immune by the methods known to science to produce such immunity. But this is a very difficult matter in the present state of the art of biochemical warfare, and of the science underlying it.

Present methods of creating immunity, usually by some form of injection, would necessitate, for an army, medical activities and organisation on a more intensive scale than appeared in the last war. To preserve the element of surprise, which is important in this as in all military attack, would be an exceedingly difficult matter, with millions of men undergoing treatment for immunity. It is, of course, true that for an entirely new form of infection it would not be sufficient to know that the enemy was rendering his troops immune to neutralise such surprise. Before counter-measures could be taken, the hostile microbe would have to be identified and a whole series of bacteriological investigations carried through. But to perform this kind of warfare thoroughly would not mean simply protecting one's own troops. Bacteria would make no distinction between soldiers and civilians, and we have sufficient knowledge of the spreading of epidemics in peace-time, under the most stringent conditions of repression and counter-organisation, to realise the difficulty of preventing the spread of this contagion from troops to civilians. It comes to this : that in any serious attack practically the whole nation, or group of nations, would require to be defended before the method could be employed.

Another difficulty which surrounds the subject is the method of conveying such hostile organisms. Many of the present possibilities are very sensitive as regards their environment, requiring carefully adjusted cultures to maintain their life and reproduction when away from their host, or the human body. There can be no doubt, however, that methods could be devised, if they have not already been worked out, for conveying organisms under conditions of war from one force to another. Competent bacteriologists and biochemists could no doubt point out other difficulties of a more profound nature, but, unfortunately, I think they could also point out many awful possibilities. Many refinements could be forecast in this particular branch of the art of war which might take time to develop, but no one competent to judge would categorically state their impossibility. Types might be bred whose action on the opposing forces depended upon biochemical contact with the body in a short period of time, after which the organism became dead or harmless. It might be possible to

put up the culture medium in such mechanical forms as were perfectly adapted to the standard methods of projecting. Under such conditions one can visualise the immediate steps of a force attained by the deadly organism, which would be to sacrifice one or more of its number in a gallant attempt to reach and infect the opposing forces—a new form of military heroism. The subject is so gruesome and repugnant that I cannot develop the clear or less obvious possibilities of the future. Various learned committees have reported to the League, admitting the dangers and urging complete and general renunciation of such a method of warfare.

THE LEAGUE REPORTS

It was in 1923 that the League of Nations called for reports from world-famed biologists upon the possibilities of the use of disease germs and similar agencies in war, not only by attacking humanity, but also plant life. It was about that time that League Committees considering the new agencies of war, and apparently unable to find practical measures to check them, were urging widespread publicity for authoritative views on the dreadful possibilities as a kind of last resort playing upon the fear and conscience of the world.

Reports were rendered by such eminent authorities as Professor Pfeiffer of Breslau, Professor Bordet of the Brussels Pasteur Institute, Professor Madsen of the State Serum Institute, Copenhagen, and Professor Cannon of the Harvard Medical School, Boston, U.S.A. It should at once be stated, before revealing any of the technical details, that these statements showed the most total disapproval and horror of bacteriological warfare ; they emphasised its inhumanity on account of the awful possibilities amongst non-combatant populations ; and the personal stress which they laid on the moral issue could be taken as the strongest evidence that such opinion does not regard these possibilities as being impracticable or remote so far as the cold technical considerations are concerned.

Briefly, they dealt with the known possibilities and those of the future. Regarding the former, they referred to the use of cultures of typhus and cholera, mainly by infecting water-supplies. Professor Pfeiffer, although pointing out the obstacles in the way of successful use by infecting the supplies of the larger towns, stated,

"There are, no doubt, other possibilities. Infectious germs might, for instance, be thrown from aircraft direct into the pure water reservoirs. In such a case the means of defence we have just mentioned [filtration] would be ineffectual." He refers to the possibilities of inoculation, but goes on, "An epidemic whose very name recalls the horrors and devastations which it caused in former centuries, and which is therefore particularly likely to spread terror and dismay, is the human plague. The most likely way of spreading an epidemic of plague would no doubt be the scattering of plague-infected rats, which might very easily be achieved with the help of aircraft. In this way an epidemic of bubonic plague might almost certainly be brought about in the trenches, which in any case are alive with rats ; in the interior of the enemy country, also, the dissemination of plague germs on a large scale would be possible, resulting undoubtedly in the formation of centres of infection." He goes on to explain that such a plague would not find its path as easy as in the past, which is not very reassuring.

Professor Pfeiffer deals also with the artificial infection of projectiles with strepto-staphylo-cocci of extreme virulence, the germs of anthrax, of glanders, and perhaps also rabies. Here again he tries not to be alarmist, and points out the difficulties, such as the durability of cultures, but admits the possibility of employing them inside shells, grenades, shrapnel, etc. Apparently the chief difficulties in his mind are associated with the continued life of the germ under the various shocks and temperatures which the projectile encounters before it reaches the enemy, and he says, "It might be worth investigating by means of experiments to what extent the most resistant germs of infection—such, for instance, as the germs of anthrax—could under such circumstances be introduced into wounds in a condition which would make them dangerous." "What would be very much more dangerous would be, for instance, if airmen were to throw glass tubes filled with virulent bouillon cultures of glanders on closely packed crowds. The shock of hitting the ground would dissolve the germs contained in these tubes in a cloud of fine infectious spray which would be very likely to cause cases of glanders by means of inhalation, and small injuries from infected glass splinters. Other infectious materials, such as the germs of anthrax, might be used in the same way."

Professor Bordet entirely concurs with the observations of his colleague, but stresses the practical difficulties, not so much of

introduction, but owing to modern methods of prevention, but makes a very interesting suggestion : " There is, however, a germ of which M. Pfeiffer makes no mention, which causes an insidious disease that is often very hard to diagnose, and which might possibly be successfully employed to harm an adversary, i.e. the micro-coccus of Malta fever. Individuals are very readily infected with its cultures, which produce a lingering disease, rarely fatal, it is true, but very depressing."

There are several references to biological warfare upon animals and plants, and Professor Bordet says, " I should not be surprised if an attempt were made one day to produce contagious diseases among domestic animals. An attempt of this kind was made in Roumania : it is well known that cultures of glanders were discovered in the German Embassy at Bucharest, with instructions for producing glanders in the Roumanian cavalry. At first sight it might not seem very difficult to propagate rinderpest among the enemy's herds. Of cattle diseases, this is certainly the one which would be most suitable for the purpose. Happily we possess means to combat this disease."

Professor Cannon comments on crop attack : " There is one aspect of warfare by action of parasites that we are perhaps rather more familiar with in the United States than in other countries. We have suffered much from the introduction of unusual enemies of our crops. A large amount of destruction has been done in this way. During the past two summers every important thoroughfare leading into New Hampshire has been guarded, and automobiles entering the State have been stopped and searched for corn. The object has been to prevent the introduction into the State of a destructive disease of that important plant. By means of airplanes large territories could be strewn with plant parasites that would undergo natural increase in numbers, and that might devastate large areas. A nation which had as great reserves as the Allies during the last war could afford to use this mode of warfare against nations like the Central Empires, which were unable to get outside supplies. There would be the same justification for using such methods as there has been in the past in continuing a siege or a blockade until the population felt the pangs of hunger.

Professor Madsen gives a balanced view of the possibilities as to the present and the future, saying, " It is obvious that the first point of view is the only one which allows of the formulation of definite opinions. I am in agreement with the conclusions put forward by Professor Pfeiffer in his memorandum on the same

subject. The means which bacteriological science possesses in its present state of development would certainly suffice to give rise to epidemics of greater or lesser extent ; airmen or persons with a knowledge of the topography of localities might infect the central sources of the water or milk supply of a big city, and thereby propagate epidemics of typhoid fever, cholera, or other intestinal diseases. Epidemics of this nature might even be fairly serious. None the less, it is hardly likely that they would have a decisive or even a very important influence on the issue of the war, for experience, and more especially the experience of the world war, has clearly shown that our present knowledge of medicine and of microbiology places us in possession of means which would suffice to limit the epidemic spread of intestinal infections, which used at one time to be so dreaded."

"It is even hard to believe that attempts to propagate epidemics of *bubonic plague* by means of plague-infected rats would give rise to any very widespread epidemic."

" It would not be safe, however, to exclude the possibility that the *future development* of microbiology might change this state of things.

" Chief consideration must be given to contagious diseases of the respiratory organs ; it might perhaps be possible to find means to increase the virulence of the microbe of one of these diseases to a sufficient degree to give rise to a violent epidemic of unlimited extent among the enemy population and at the same time to preserve one's own nationals by means of vaccination or sero-therapy.

" I would mention more especially pneumonic plague and pneumonic glanders, apart from diseases arising from microbes at present unknown ; likewise influenza and its complications, a disease of which the causes are at present very incompletely known. The voluntary propagation of influenza epidemics even more serious than the last general epidemic might perhaps be possible in the future."

It is a relief to turn from these horrors to more constructive views. We are bound to admit from such authoritative evidence that disease warfare is a possibility even in the present state of knowledge. Further, no fundamental consideration imposes a limit on the dangers inherent in the future development of the science ; they may be small or very great, and it is for us more or less a matter of chance. It is perfectly clear, however, that these eminent experts are to a certain extent looking for safeguards in

the present difficulties of the military application of micro-organisms. What is the value of that safeguard? Such application is a special technical problem which, so far as we know, and we hope, has never yet received any substantial consideration by those qualified to promote it. But chemical warfare was in this position in 1914, and three or four years of intensive work in military use bridged a gulf which otherwise was a decisive obstacle. Is there any reason to believe that the ingenuity and scientific momentum of man could not do the same in this new field of bacteriological war? It is only a personal opinion, but one based on intensive parallel experience, that a determined effort, with proper scientific assistance, would be extremely likely to create the most successful or dreadful possibilities.

Then, again, the safeguard which constantly appears in these reports of modern knowledge as to counter-measures and methods of prevention may easily be exaggerated. Examples from peace must be treated very carefully. There we have the incidence of micro-organisms and disease from rare and casual causes upon great nations with medical organisation alert to crush the threat at the remote points where it may arise. Preventive measures are usually extremely local. But in war we should have a comprehensive and consciously directed introduction of the infection maintained at all kinds of unexpected places. The new problem would not be so much one of knowledge, but of organisation, out of all proportion in magnitude to the admirable efforts of peace. Consider for a moment an example which may not be very apt, but is at least within the bounds of reason. Some of the organisms referred to might produce diseases which require oxygen treatment. Now if an attack of this nature were to be made, producing hundreds of thousands of casualties requiring such treatment quickly, it would take us far and away outside our normal medical facilities both as to oxygen, appliances, and skilled personnel. The special difficulties of medical treatment of enormous numbers of the same type of casualty arose acutely on one or two occasions at the front, and in the face of the most intensive organisation, which at times it threatened to overwhelm. But the variety of agencies causing casualties was so great, and the cases of floods of casualties of the same type were so rare, that it only served to indicate a new threat in the future. And this would be far more likely to arise from the widespread use of bacteriological warfare and its peculiar propagation of effect than from any older form of weapon in which a main characteristic is that results are

limited to the casualty attained, and at the most, as with gas, to a limited area.

There can hardly be any doubt that bacteriological warfare holds very serious possibilities at present, possibly much more potent agents in the future, and that it presents a new type of problem, and a most difficult one to medical organisation. In developing these sciences, which are full of deadly military possibilities, mankind is playing with fire unless positive steps are taken to prevent the use of his greatest boon for his own destruction.

We require no further examples or argument to justify our assumption that the new agencies of war are a very serious factor in armament and disarmament. There is no question that development is limited on purely scientific grounds, but, on the contrary, it appears to be practically unlimited. All branches of science might contribute, but under immediate unrestricted development the chemical branch would be likely to prove the most fruitful. Finally, the nature of such development is not adequately represented by the idea of a spontaneous discovery, but, as we have shown, and will further show, it is a growth built up of a series of fairly well-defined steps, similar to the process of turning a scientific invention into an industrial success. If, therefore, disarmament is possible in this field, either entirely, or to a limited extent which is worth while, the methods should be exposed in attempting to answer the following question : What can be done to check each step in this growth if we apply the same cold thought and determination which characterised the converse process, the development of armament, during the war ?

CHAPTER X

APPLIED DISARMAMENT: THE NEW AGENCIES OF WAR

The Fallacy of " Discoveries " : The Prohibition of Use in War : Prohibition of Preparation : The Graded Stages of Development : The Research Stage : The Private Investigator : The Scientist's Dilemma : The Scope of the Problem : The Attitude of Science : A Practical Step : The Freak Invention : The Intermediate Stage : Official Half-Scale Work : Private Half-Scale Work : The Defensive Type : Large-Scale Work : Existing New Agencies

Disarmament theory in relation to the new agencies is concerned only with weapons which are still unborn ; but in application there is another very important aspect to be considered. There are certain weapons of very recent origin, which must be classed as new agencies, but whose arrival and growth, during the war and after-years, present a specific problem. Thus, if a means can be found to check the military application and use of entirely new discoveries in the future, it does not follow that it will apply to the new agencies which received partial development in the recent war, and since. The simplest way to deal with this subject is to consider disarmament in relation to future new agencies, and then to examine what special steps are involved in dealing with those which have already arisen, and are even now growing to maturity.

THE FALLACY OF "DISCOVERIES"

A discovery is not a weapon, although it may eventually produce one. Disarmament advocates are liable to have such a limited conception of a new weapon, and be so alarmed by it, as to urge panic measures. These damage disarmament. Examining what has been said and written on this subject since the war, one gets the idea that the new agencies have been regarded as a kind of spontaneous outbreak, a series of uncontrollable brain-waves, cropping up in the same unsuspected manner as an epidemic of disease. This limited conception has plainly governed the nature of official action on chemical disarmament up to the present, and no doubt largely explains why the broad problem of the development of armament type has been neglected. The

records of the Washington Conference and the terms of the Treaty of Versailles show how far and frequently this inadequate view of the new agencies of war has been an obstacle.

Let us glance for a moment at the Versailles Treaty, which imposed disarmament measures upon Germany. We have no intention or desire to discriminate against that country, but simply use the clauses as an approach to the problem. We must assume that it was the intention of the Allied Powers to prevent the further development of German chemical warfare, and Article 171 is apparently the only clause which relates to it. The clause reads :

> " The use of asphyxiating, poisonous, or other gases and all analogous liquids, materials, or devices being prohibited, their manufacture and importation are strictly forbidden in Germany. The same applies to materials specially intended for the manufacture, storage, and use of the said products or devices. . . . "

We have a clear reference to prohibition of the use of chemical warfare, but, seeing that Germany was then regarded as already having violated such prohibition, and that other nations followed her in this respect, it might well be thought that something else was required to support it, and thus we find certain restrictions. Manufacture and importation of the chemicals are forbidden, and this is reinforced to a certain extent by including materials specially required for the manufacture, storage, and use of the chemical weapons. So far as actual measures during peace are concerned, the Article regards the denial of manufacture and importation as adequate. Importation is relatively unimportant in the case of a nation possessing the most powerful chemical industry in the world. The prohibition of manufacture would be powerful had the Article been applied to a country for which manufacture meant the creation of an industry, but in the case of Germany her production lag, and therefore this particular safeguard, were at a minimum.

There seems to be no recognition whatsoever of all the other steps vital to the development of chemical warfare and its devices, and Article 172, the only other reference to the subject, is hardly more comprehensive. It reads as follows :

"Within a period of three months from the coming into force of the present Treaty, the German Government will disclose to the Governments of the Principal Allied and Associated Powers the nature and mode of manufacture of all explosives, toxic substances, or other like chemical preparations used by them in the war or prepared by them for the purpose of being so used."

This measure can well be understood in view of the state of mind of the Allied Powers at that time, as a safeguard against any new poison-gas which Germany might have had "up her sleeve," but it leaves untouched the real problem of future development which we are discussing.

The proposal brought forward at Geneva to check new weapons a year or two after the war, and very seriously considered, is again coloured by the same idea of the impossibility of harnessing the chemical weapon, because its life-history has the short and sudden nature of an irresponsible discovery. They proposed, as a measure of chemical disarmament for all nations, that each should expose to the League, for disclosure to others, the particulars of any new discovery as it arose. Such a proposal, even if carried into effect, would have a very limited value. In some directions, the most important, it would lead to instability, for some nations have a very strong chemical manufacturing organisation and powerful means of investigation and development, while others have practically none at all. The actual result of such a measure would be to present the strong chemical nation with a large choice of new weapons to which it could give rapid practical expression, while others, feebly organised, would be no better off than before.

One can imagine the U.S.A. coming forward with Lewisite or some critically important new chemical device. What would be the effect of throwing the new discovery into the field of European armament competition? In this field at such a time, as at all times in the absence of disarmament, there would exist wide disparity as regards new types of weapons possessed by the various possible enemies. Some of the nations would be equipped to make rapid use of Lewisite for war; it would be a real addition to their chemical armoury, whereas others could do no more than file the report distributed through the League. In actual effect the previous disparity would thus be increased, a result opposed to the proper objective of any true disarmament measure.

In one respect the proposal is less open to criticism, for it would inform nations of the dangers to which they were exposed, and in theory enable them to develop means of defence should such be possible. But in the field of defence the same differences in the means of production and investigation would exist, and, if the discovery related also to defence, the disparity would again be increased. It is interesting to note, however, that the defensive side of this proposal could be coupled with certain other measures which would give it substantial value, and we refer to this in the present chapter under the heading " The Defensive Type."

THE PROHIBITION OF USE IN WAR

So far we are faced with inconclusive measures and proposals which really go no further than prohibition of use in war, and without going into the disarmament history of the last ten years in detail, we can state with certainty that so far as action is concerned only prohibition has emerged, and the net result is the Protocol prohibiting chemical and bacteriological warfare, which has been ratified by various nations, including our own.

We have therefore reached prohibition of use of two new weapons as the maximum existing contribution to the whole problem of disarmament of the new agencies of war. Is there any reason to limit this prohibition to two types only? There is, of course, no such reason; in theory all the new agencies have the same bearing on disarmament; but there is the practical point that disarmament conferences and national representatives can more easily bring themselves to deal with dangers which they can readily visualise.

May we assume that as new weapons arise the same prohibition of use in war will be applied? The present state of armament development would not justify this assumption. New agencies are emerging in the field of small arms and tanks to which official disarmament does not appear to have given a thought. But this may be due to the fact that the question of new armament types has never been considered as a basic and urgent problem. Let us assume for the purposes of our discussion that chemical warfare will not be regarded officially as an isolated case, and that other new agencies will be brought into line. A most important question at once arises. Mere prohibition has proved a broken reed in the past. That is no reason for not prohibiting. But can anything be

done in times of peace to assist and render more effective the prohibition of use in times of war?

PROHIBITION OF PREPARATION

Nations at present have every liberty to prepare for the use of a weapon which is prohibited, and, indeed, several great nations are making active preparations. At the same time we must consider that a nation or a group of nations agreeing to the prohibition of use in times of war fully intends to refrain from such use. Any other view would be futile. The absurdity and the danger of the position have been fully realised, and disarmament records leave no doubt that the great statesmen of the world working for peace are acutely aware that something else is needed. The broad question whether the prohibition of use of a weapon in war can be supported by any measures in times of peace has figured largely in the records of disarmament, but it has never received a satisfactory answer, and it has even been implied that there is none.

Now there is one obvious and possible step. It is a farce to call off the armament race in the old weapons and leave it in full blast for the newer weapons which will make them obsolete. In the case of Germany, the Treaty-makers were obviously seeking for a formula to cover the prohibition of preparation, and this in simpler and more general terms is what is required for the broader problem of general disarmament. There is no need to confuse an agreement on such prohibition with the working out of detailed measures to support it. We either do or do not want these preparations to go on. There is only one position consistent with disarmament, which is that they should cease. That being so, why afford preparation the most complete international sanction, and why should it not be prohibited? Such is, in fact, the most important next practical step which disarmament could take in this field.

The objections which could be raised against such a measure are quite clear, but they appear to me to be outweighed entirely by the advantages. A narrow national view would be that whereas one nation would, the other might not, honour its covenants. Which is the sounder position, unlimited preparation, or its general prohibition? The analysis of this problem is quite simple. If we assume that breach of covenant makes prohibition of preparation useless, then what must we say about prohibition of use in

war, a thing over which, in the absence of prohibition of preparation, we have no control whatsoever? If we apply the argument to the one case we must apply it to the other, and the prohibition of use in war—in fact, the whole question of disarmament—falls back to the status of an interesting academic problem.

On the other hand, if preparation be prohibited, we have safeguards against the breach of such a covenant: we have possible forms of control in peace which, if operated, would enormously strengthen the effect of prohibition of use in war. Here we come to matters of fact. Can a nation undertake effective preparations in violation of its covenant without discovery? If it can, the objections to prohibition of preparation must be heard; but if it cannot, then all the general measures employed in a disarmament treaty to assist its performance come into play, and to the extent that such measures are comprehensive and technically sound, so the possibility of outlawed preparation becomes remote.

We are again brought down to armament facts. Whether effective preparation can be made in secret depends entirely on the scientific, technical, and industrial nature of the activities involved. On the view that a new weapon is only a discovery the position would be hopeless, but on the basis of a real examination of such preparations in terms of the study of armament, keeping close to facts and avoiding loose generalisations, the situation can be dealt with.

From this point of view disarmament in the field of the new agencies of war must be based on a technical study of the matter. It is largely because this has not been done that so little progress has been made. This is the first reason why our study of scientific disarmament would not be complete without a real examination of what is involved in the development of a new agency of war; but there is another.

Even though it be accepted that the prohibition of preparation would be a valuable disarmament measure, we are still faced with the question which has puzzled the official disarmament world: Are there any detailed measures of disarmament for the new agencies of war which could be applied, as distinct from, and in support of, general prohibition of preparation? There is only one satisfactory approach, which is again to make a close analysis of preparation itself. On the view taken at Washington and elsewhere that new weapons could spring up in a few weeks, and on the basis of the fallacy that a weapon is simply a discovery, the

question of detailed measures becomes impossible. It is inconceivable how these ideas have obsessed many statesmen in approaching this problem, for even the non-technical disarmament advocate should not proceed in a vacuum of fact ; he should be guided by those which are available to all, and should at least employ the great amount of information surrounding the subject which arose from the experience of the recent war, which in no way and in no single case justifies the present position of stalemate.

Let us briefly review the position which we have reached. The logical requirements of disarmament in regard to the new agencies go beyond the prohibition of use in war, which, as we have seen, is in two cases an accomplished fact. They require, first, an agreed prohibition of preparation. Here we shall have to examine in broad outline the armament history of a new agency of war to see whether such prohibition would really impose material obligations upon the nations which undertook it. If a new agency can mature from an inventive thought-process to war use in a few days, prohibition of preparation has very little physical meaning, but if, on the contrary, ample organisations are required in which long and arduous work must be done by numerous and special staff with official administration and financial support, then prohibition would imply drastic and known changes in national armament activities. It is therefore essential that we should be able to form intelligent judgment whether under such a regime of prohibited preparation nations need stand in angry anticipation, suspecting others of violating their covenant, with no means of finding out. If our examination can provide an answer, it is of the utmost importance, but it may also lead to the second objective. The facts may show, not only that a real physical restraint would be involved, the evasion of which could be discovered, but they may point to detailed measures in support of the prohibition, which would remove any possible doubt that disarmament of the new agencies was not effective.

With this double objective we proceed to examine some of the facts which surround the development of the new agencies of war as revealed by their inherent technical characteristics, and, perhaps more convincing for the non-technical reader, as shown by the life-history of the new weapons which emerged under the feverish impulse and development period of the Great War.

THE GRADED STAGES OF DEVELOPMENT

What do those facts tell us? It is now fairly well known that after the first German gas attack, in April 1915, the British made very strenuous efforts to reply with the same weapon. A decision was rapidly made. So far as the discovery of the gas was concerned, there was none to make, for it already existed. We knew within a few hours of the German attack that they were employing chlorine. Now, if the discovery alone is the all-important thing in chemical warfare, the British should have been able to reply within a short time, say a few days or, at the most, weeks, but, working with all speed available, we were not able to launch a gas attack until September 1915, and then only in a mild fashion. What was happening during these six or seven months? Very briefly the position was as follows. We knew that we wanted chlorine, a substance which every schoolboy handles in the chemical laboratory. There was no question of waiting for some group of highly trained chemists to discover the product. But we also required chlorine in a form which could be used as a weapon on the front, which implied, not only chlorine in liquid form, and not only the proper container, able to withstand the pressure and to release the gas through trench-proof and fool-proof valves, but also methods and appliances to launch it on the enemy.

The first problem was to attain adequate quantities of liquid chlorine. The capacity of the country for the production of this commodity was very feeble, the bulk of the product in the past having been produced as a gas and rapidly converted into other commodities, such as bleaching powder, without the isolation of the element in liquid form. An effort had to be made, therefore, in existing chemical works to expand the manufacture of liquid chlorine from the very small existing unit. Designs of suitable discharging apparatus had to be drawn up and tested on a small scale in the chemical works; but, having reached this point, it was quite impossible to rush into bulk manufacture, and this for a very simple reason which is so often ignored.

A new weapon cannot be used on the front until it has been extensively examined in what we may call field tests. All kinds of points have to be satisfactorily settled, such as the best method of operation and installation, the feasibility of use by operators, their danger and adequate protection, the density of such appliances along a unit length of front to produce dangerous effects at a given distance, and the most suitable wind velocities in which to

operate. Above a certain velocity the gas disperses so quickly as to be practically harmless, and below another velocity its removal is so slow and uncertain as to endanger one's own troops, quite apart from the discharging personnel. All this work takes many months to complete, and there is no doubt that when the Germans launched chlorine in April 1915 they must have been working in laboratories, works, and experimental grounds for many months. Broadly speaking, therefore, although they made us a gift of the discovery that chlorine was a valuable weapon, it took us six months of feverish work, in manufacture, small-scale, and field tests, before we were able to make any kind of reply. Even after works tests and field tests at Cannock Chase and other places were completed to the satisfaction of the home authorities, the field companies had to be organised and practised in the art. For example, in July 1915, two months before the first British gas attack at Loos, the problem of organisation and training of field personnel had become as acute as the more technical problem of material and design. Many Englishmen, and the long-suffering inhabitants of surrounding villages, will remember the feverish training on the gas-bleached fields and commons of Helfaut, near St. Omer.

It is possible for anyone conversant with the facts to analyse all specific poison-gas development in this way, and we find that, far from a discovery being of itself a potent factor, it is but the first small and intrinsically ineffective link in a long chain of development ; and equally in disarmament, a new weapon or a new agency of war must not be viewed as a discovery, but as a growth, i.e. as a series of distinct steps. As soon as this point is grasped, the task of disarmament becomes quite clear. It is a question of considering each step in turn, and of devising means of stifling this growth at every available point.

The nature of these steps has been indicated above, and it would be useful to summarise them here. The first—discovery or invention—is self-evident. In common with any other scientific invention, the birth of a new weapon arises from newly discovered facts, or new combinations of things already known, leading to a new material or device. It would be well to make it perfectly clear that this first inventive step is by no means instantaneous. There is no such thing as the overnight production of effective discoveries, either for peace or war. This first step in armament development is always accompanied by investigation, dealing, say, in chemical warfare with methods of preparation of small

quantities, searching examination of properties—not only physiological work uncovering the harmful reactions on man or on other creatures, but general properties, particularly those bearing on later manufacture and the wide range of problems involved in military application.

Indeed, in any field of applied science a great deal has to occur between the first suggestion, the inventive spark, and the time when one can say that a proved discovery has been made, a new contribution to industry or war. We visualise an investigator striking a new chemical product, a mechanical or electrical device. He usually does this by means of a courageous combination of imagination and reasoning, starting from the existing level of scientific knowledge and going a step in advance of it, or else he may make some important observation in the course of practical work directed towards a different objective. In this way the new idea emerges, and possibly a crude practical expression of it, which may be a trace of a laboriously prepared impure chemical, or a very simple or quite impracticable electrical model. At this point the investigator is usually quite impotent so far as application is concerned, either for industry or war.

The record of modern invention leaves this point beyond doubt. Some of the most brilliant inventive minds, well supported, such as Edison, Maxim, Nobel, or some of the brilliant chemists surrounding the great German chemical combine, often spent years of active development before they could convert the first inspired flash of discovery into a proved proposition which could be exploited by the great industrial organisations with which they were associated.

We have the fairly recent case of the German specifics—new synthetic organic chemicals—for the scourge of sleeping sickness. Long before it was possible to make even small bulk quantities to accompany the expedition to tropical Africa to test the material there was a period of some years during which the invention was labouring from birth to practical proof, when it was not at all established that commercial application would be realised, and during which long series of small-scale practical tests were going on. Here the chemist was co-operating with the physiologist, pure and medical science went hand in hand, and the product was being varied in composition and physical properties in order to satisfy the final medical objective. Indeed, if one were seeking a peacetime example or parallel of the development of a chemical as a new casualty-producer, it would be difficult to find a better

case than the one mentioned above. We are all acquainted with artificial silk, of which there are various chemical forms. Commercially the most important is probably viscose, which is based, like the others, on its own special form or derivative of cellulose. The discovery of cellulose for viscose, the work of bringing the new chemical to a state of knowledge and control from which it could be applied industrially, and with which the names of Cross and Bevan are closely associated, took something like twenty years. There were probably special reasons for this: well-established textile industries based on natural fibre, the revolutionary nature of the idea, and others; but the fact remains that the elimination of such difficulties would still have left a number of years of patient development work before viscose could have been regarded as effectively discovered in the sense of our discussion.

There is no reason whatsoever why these characteristics should be limited to peaceful discoveries, and should not carry over to inventions for war. Indeed, it is incredible how a generalisation regarding discoveries, which would have been swept aside at once in any serious industrial discussion, should have been allowed to take root in international affairs to such an extent as to shape their course.

Examples from chemical warfare are numerous. One knows how the French sought new products in the chemistry of cyanogen; how they tried to move from the prussic acid type, such as Vincennite, to more complex derivatives, such as Mauginite, a form of cyanogen chloride. This product, on which great hopes were pinned, did not emerge from the discovery stage for many months, and this is also the case with another range of products to which the British attached great importance—the complex organic chlorarsines which were to be liberated in huge quantities in the form of a smoke had the war continued.

Emerging from discovery, we reach two diverging lines of investigation on a semi-industrial or middle scale, relating, respectively, to manufacture and military application. As to the former, it is rare even with harmless commercial products for bulk manufacture to be designed and operated straight from the research stage. There are too many unknown factors to render this a reasonable risk, either for commerce or particularly for war. Design of plant, heat exchanges, methods of handling, dangerous residues, and a host of other points require investigation on an intermediate scale before proceeding to the actual works.

Then on the side of military application it is practically impossible to proceed to field use, even when bulk supplies are available, without work on an intermediate scale dealing with containers for the chemical, whether shell, atomiser, projector, etc. —bursting and propellant charges, filling methods, non-corroding containers, storage, and many other points of great importance. It must be remembered that military responsibility in matters of this sort is by no means small. No staff can lightly embark on bulk use of a new chemical device without really adequate assurance as to safety of operators, surrounding troops, home storage, and field dumps. With these two intermediate periods bridged, there remain the two further substantial steps of proving bulk manufacture and field use, the former implying a plant and works, and the latter extensive field testing stations, both with adequate personnel.

In some cases the nature of the problem will be such that one or other of these stages presents less difficulty and absorbs less time, or they may merge into each other, or, again, one particular stage may present abnormal difficulty. I do not pretend that in every single case one can work on a fixed and unchangeable programme. Nevertheless, these steps have been found substantially to accompany the development of a new chemical weapon in the past, and on a theoretical basis, or by analogy with similar activities in scientific industry, they represent the logical needs of the case, and will doubtless hold good in the future.

It will be noticed that, in discussing below the possibilities of operating disarmament measures over the different distinct steps of development of a new agency of war, the examples employed are almost entirely chosen from chemical science and chemical industry. One good reason has already been given for this, which is that no single individual can claim expert knowledge on the whole range of science and industry underlying armament, and the special knowledge of the writer relates to the chemical side. At the same time, it is not desirable that the impression should be created that this weakens the argument, either for or against disarmament, in the new agencies of war. It is a solid fact that, although we may employ this term in a general way, yet to-day the new agencies of war centre round chemistry.

THE RESEARCH STAGE

There are, from the disarmament point of view, two classes of research or small-scale investigation, i.e. work under Government direction or control, and purely private effort. The former requires very little attention here. Obviously nations loyal to a covenant prohibiting chemical warfare or other forms of arms development would suppress official research stations, whether in their own official establishments or in University laboratories, or wherever they might be. If the covenant were less drastic, then whatever regulations it imposed or sacrifices it demanded could be honoured and maintained in official or controlled establishments.

THE PRIVATE INVESTIGATOR

There remains private research, which introduces a very big problem—one never yet faced, and, in fact, not recognised—still on the distant horizon of the politics of peace. What is the position of the scientist and investigator as regards disarmament and peace? It is, in fact, a very difficult one, and in principle the same, to the best of my knowledge, in all the great countries of the world. Most of these have their nucleus—sometimes a very substantial one—of official chemical warfare investigation. Workers are following up various lines suggested by war results and experience, or by pure science, or by the combination of both. The work goes on in official laboratories and sometimes in the civil research organisations of the country, such as the University laboratories. The ordinary investigator knows quite well that this work is going on, and it is a most natural thing for his mind to turn to the military applications of his own work.

For example, no chemist, whatever may be his feelings regarding disarmament, can fail to have a general idea of poison-gas work during the war. So many accounts have been published dealing with various aspects of the matter from a popular or scientific point of view. It will be clear, to any discerning technical mind, that many lines of investigation have been opened, in some of which productive work of use for war could be done, and contributions made without employing any poison-gas or war chemicals during the investigations. Thus it was apparent in the last stages of the war that Germany was seeking a method of

rendering phosgene more harmful by increasing the stability of the chemical contents of the big mortar bomb. They were trying to make the material last longer in any place where the bomb might have dropped, so that it might attain the maximum number of men and produce maximum casualties before it dissipated into harmless concentrations. The Allies, on the other hand, were pursuing a somewhat similar objective in their efforts to change the nature of the lethal chemical cloud from one of a truly gaseous nature to another of the smoke or atomised solid type.

I well remember the last and critical step taken at the end of the war to bring this matter to a head. A new weapon had been devised by the Allies for the generation of poisonous smokes. The device was new, and the chemical concerned had new characteristics. It was capable of producing weird physiological effects upon a human being, already hinted at in previous references to organic arsenic compounds. It was a refinement upon previous efforts, not only causing what we might call a chemical casualty, but producing curious mental states of great pain and confusion sufficient to neutralise the military efficiency of a body of troops. Physically it was a threat through its increased power to penetrate the main line of defence, the enemy mask. It remained effective so long in moving air that there seemed to be no place in the British Isles where it could be safely tested, even on a relatively small scale. Conferences occurred in Paris with the object of deciding a testing-ground, and also of discussing the best time and occasion to employ the new weapon to give the maximum surprise effect. The enemy was expected to take up a formidable line of defence in the spring of 1919, and this weapon would undoubtedly have been employed to break down that defence; happily, hostilities ceased before the occasion arose. In any case, a wild stretch of country on the Mediterranean coast adjoining the Rhone mouth was set aside for the test. British and French units were taken south, with small supplies of the new chemical weapon. A front of a hundred yards or so of relatively low chemical density was arranged, giving a reasonably safe range of about twenty miles for observation on the effect of the chemical. At intervals of a few hundred yards observers were posted for several miles. Those nearest to the point of emission were equipped with the British mask, which had maximum protection, and those farther away had the German mask. Penetration of the latter occurred at long distances. Unprotected civilians and animals

were attained at several miles' range, and it was found that the precautions which had been taken were more than justified. I am digressing from my argument, but this is a wonderful example of the kind of step which has to be taken before a chemical weapon can safely be employed by a military staff, and it shows the importance which the chemical smoke form of attack had already reached.

Now it would not be difficult to find investigations going forward to-day in pure or applied science in which the results might have considerable bearing on the two problems referred to above. The work on the purification or separation of industrial gases by absorptive methods might be said to have peculiar bearing on the phosgene problems, and much light might be thrown on the toxic smokes by investigations on the large-scale sublimation of organic compounds or physical work on fogs in town atmospheres. Assume for a moment a combination of circumstances of which one could find a number of examples in actual life, i.e. a scientist in a pure or industrial research laboratory, well aware of chemical warfare requirements and working on problems similar to the above. Now his work may at any time reach a point, although designed towards a purely peaceful objective, when it would seem that a certain amount of investigation on slightly diverging lines would forge some important link in the chain of war chemical development.

THE SCIENTIST'S DILEMMA

We can see the investigator's dilemma. Patriotic motives and possibly personal profit would urge a man to exploit this military possibility to the maximum. On the other hand, disarmament considerations would block any such avenue.

The line of conduct for a military investigator in the Government service is perfectly clear. He is paid to make contributions towards armament, and scruples, if any existed in that direction, have already been disposed of when he entered that particular service. But for the private investigator the position is not clear, and is becoming every year more difficult. Half a century ago there was no vigorous disarmament movement, the world conscience had not been seriously stirred in that direction, and Governments certainly had no definite element of policy or obligations relating to disarmament. But to-day the position is

obscure, inasmuch as a Government pursuing armament development is also committed to a disarmament policy. To-day, therefore, it would be quite feasible for a patriotic investigator, confronted with the possibility of important armament development, to feel it his duty vigorously to pursue it, but it would be equally possible for an equally patriotic worker favouring rational disarmament definitely to submerge such results and such development under similar conditions. Both positions are quite logical within their separate premises. Very broadly, a new situation has arisen in armament development. The investigator is faced, for the first time, with a genuine doubt as to his course of action when he finds himself able to foster new armament. It is a difficulty which applies not only to the chemist, but to the scientific class as a whole, of which, in regard to armament, he is at the moment the chief example.

THE SCOPE OF THE PROBLEM

We are leading up to the reasoned requirements of disarmament in this field, and the first idea which arises—by far the easiest line to take—is that the field is too complex for anything to be done. There is also a natural reaction against imposing restrictions upon scientific work. But these are only emotional viewpoints, and, if we allow them to guide us, the dangers are real and the future is vague.

Several great countries have been pushing armament research during the last few years in Universities and similar places in a veiled and somewhat halting fashion, rather anticipating that international agreement would eventually remove the authority, support, and standing which such work now enjoys. But take away this obstacle and imagine for a moment that world disarmament halts at the stage of budget limitation, as, indeed, seems likely to-day, leaving the greatest freedom for development within such limits. Nations then, particularly the more highly scientific, will undoubtedly concentrate all efforts on the development of new types, the flimsy barriers will be down, and we shall find the somewhat reluctant armament contribution now being made in remote corners of Universities and similar institutions changing into a steady wave of enthusiastic progress, and, if our reasoning is well founded, another great threat will be forming, bringing nearer the shadow of war.

Present activities, if they were known, might give little justification for alarm, but that is beside the point, for the policy and expansion which they represent are one of the gravest problems of disarmament. We must therefore look more closely and coldly at the facts, and not be baffled by their apparent complexity. Where would such work occur? It must all start in a laboratory or workshop of some sort.

Fifty years ago the world's facilities for research and scientific investigation, not only in chemistry, but on all aspects of pure and applied science, were very largely covered by the Universities. This was still substantially the position late in the nineteenth century, although by then there had arisen large and notable exceptions in some of the great industrial concerns. To-day we have to consider other great categories.

There are the Government laboratories and establishments which have arisen in a service capacity in national administrations, such as the various analytical, mining, and agricultural centres of investigation. Many of these were brought into the programmes of investigation on poison-gas and other weapons and accessories related to all three branches of the fighting services. There is a further very large and increasing group controlled and supported jointly by industry and the State, as, for example, the numerous well-organised research stations which have come forward in England under the stimulus of the new Department of Scientific and Industrial Research. It is not suggested that any of these organisations have made armament contributions, although it would not be unlikely, nor, under present circumstances, improper in any way.

Further, we have a wide and increasing range of important independent research establishments. Almost every great country has powerful institutes for physiological, biochemical, and bacteriological work—witness the Pasteur Institute in Paris, and the Lister in London—and again we find springing up, by means of private endowments, great centres such as the Mellon Institute in the U.S.A., with a very broad industrial objective.

Finally, amongst the major groups we have the vast laboratories of industrial firms, some of them with hundreds of chemical, physical, electrical, physiological, or bacteriological investigators. These made their great contribution during the war—witness the poison-gas work of the German chemical group.

Then outside this solid and growing core of research

capacity we have a number of smaller but virile centres, such as the laboratories of consultants and private scientists.

Here we have a hive of scientific activity, a picture of hundreds of institutions in a great nation fostering the scientific work of thousands of specialists capable of contributing to armament development. Release them for the purpose under definite policy and organisation and, even though only a fraction be involved you introduce one of the most powerful agencies yet known, making for that armament disparity which leads to war. Can anything be done? The obvious answer is that if these facilities can be positively organised for war preparation, then they can be brought into a scheme of war prevention.

During the war it became necessary to mobilise every ounce of possible scientific support in these widespread and non-symmetrical organisations. This was done swiftly and without great difficulty, for the personalities concerned, almost without exception, were related, professionally or through qualifications, to Universities and professional or technical organisations, whose linkages were active, elastic, and maintained by that curious quality of loyalty and *esprit de corps* which exists in this field, largely due to the fact that its members talk the same language and submit to the same type of mental standards. We can say at once that for the promotion of war there was no difficulty, or, rather, no final obstacle in the way of effective national organisation with a common policy and objective, and, more than that, international linkages and organisation were swiftly and smoothly brought about so that, for example, in the chemistry of war, work going on in the most remote corners of the Allied countries was centralised and distributed from Paris with unusual flexibility and speed.

This national research capacity represented, and still does, a very powerful factor in the forwarding of new armament types. Ten years of peace conference and attempted organisation have failed to appreciate the importance of this factor for disarmament, and have indeed ignored it altogether, so much so that in the absence of any converse policy, or of any suggestion that it might arise, it appears that the Great Powers are again starting potentially, and in some places actively, to mobilise these forces for armament development. Science as a whole has made no protest, for the two main reasons that the issue is still in practice narrow and national, and, secondly, its international bearing on the

organisation of peace has not been consciously examined, far less established.

These forces were mobilised for war, and their demobilisation in the interests of peace should neither be so complex nor difficult. There are far more University authorities and prominent technical men in all countries who would regret to see a vast machine come into being to foster the new agencies of war than would welcome it, and the majority would lend their prestige, encouragement, and assistance with great reluctance in the absence of national emergency. Further, it is not a question, as in the case of war, of the co-ordination of a mass of complex scientific work, but simply the maintenance of inactivity in a given direction, required and sanctioned by international and national policy.

University laboratories are financed by various methods, and in most cases they operate together. The State first of all makes its contribution, and there are very few University laboratories to-day which are not so assisted through the general University funds. The next great source of support is found in endowments by trusts or private benefactors, or by big industrial firms. Students' fees rarely—in fact, hardly ever—cover more than a fraction of the actual expenditure involved. Now, it should be a perfectly simple matter for the State to make any contributions towards research conditional on an absolute prohibition of the use of such funds for forbidden armament development, and with a lead of this sort is it too much to suggest that the big trust endowments, such as those of Rockefeller or Carnegie, should impose similar conditions? A study of these endowments renders quite clear what is generally recognised—that scientific investigation must not be saddled with any restricting clauses. If ever a special case existed which justified departure from such a principle it is the cause of world peace. Universities would not find it difficult to prevent any such work in their laboratories by exacting from prospective students an undertaking to that effect. Indeed, their authority is such that they would not have to proceed to the indignity of such a measure. As regards the financing of research in Universities by industrial concerns, that would probably be covered in another way. There might be some general obligation in law upon such concerns that none of their funds should be used in manufacture or in any other way to further unauthorised armament development, and this would of course automatically cover the use of such funds in assisting University investigations.

A very high percentage of all this potential armament developing capacity is under official control either directly or through some connection such as financial support, which is also capable of carrying policy, not only to further armament, but, if necessary, to stifle it. National legislation in support of international agreement, could produce the desired effect in all such cases with the greatest of ease, and in fact these are the categories which involve so much direct control that legislation is not so important as it would be to impose international policy upon the remainder of the research capacity which is in purely private hands.

Assuming that disarmament goes forward comprising some measure of standardisation or restriction of armament development and type which would govern the actions of research organisations, the need of legislation depends very much upon the attitude adopted by the scientific and technical world. For this alone, if carried into organisation and thereby focused on the screen of world opinion, might convey sufficient assurance without legislation, which is to be deplored if not actually necessary. Thus one could see the position consolidated towards security by action on international lines on the part of the great scientific societies and professional organisations, with positive support through patent legislation and regulations governing the actions of their members, to such an extent that direct legislation was unnecessary.

Let us now review the position which we have reached. The first disarmament requirement in this field was the prohibition of use in war. This has been partly realised under international agreement. The next is prohibition of preparation during times of peace, which has hardly yet been contemplated. Reason would suggest, and world opinion may require, measures in support of this prohibition of preparation, physical and visual assurance of its operation. For this purpose disarmament requires a background, a general attitude towards such work, under which no investigator need contemplate the development or exploitation of any of his ideas in the direction of prohibited armament. This means that science must acquire an organised viewpoint on a matter where at present it has none ; it must remove the scientists' dilemma. The scope is new, but the idea is not, for we have a parallel in medical work, in which certain undesirable practices, with difficulty controlled by law, are effectively submerged by a tradition supported by the action of powerful professional organisations.

The logical development of the subject goes further ; it suggests

detailed measures which may be found vexing and unnecessary. Thus, for instance, one of the motives of such work is profit, which receives the assistance and protection of the community through law. Patent legislation is one example, and its revision to discourage instead of encourage the development of inventions in the field of prohibited armament would be an obvious example of the detailed measures in question.

It must not be thought that this is the kind of thing which the community would not contemplate, for we in England are at present engaged in the serious consideration, scientific and public discussion, of the position of medical patents. There has been a growing volume of opinion that the present patent law tends to the exploitation of certain kinds of medical inventions in a direction which is not consistent with the maximum public benefit. The merits of this controversy are not before us, but the fact remains that in one case change has already been made, and drastic revision is contemplated in another. The parallel with war inventions is complete, except so far as action is concerned.

THE ATTITUDE OF SCIENCE

One could go on to suggest checks of this sort, the cumulative effect of which would give the desired result, which is the reduction to the minimum of the possibility of war chemical or similar armament inventions springing up from unauthorised private investigations. This is not the place, however, to suggest a detailed scheme, as a matter of that sort should be undertaken by a panel of technical men representing through their organisations the great bulk of the research capacity of the country in question. Naturally the impression received after reading the above suggestions, or in considering the recommendations of such a body would be one of a series of clumsy, hampering restrictions, the operation of which would represent rather unusual interference with individual liberty of action, and a considerable amount of inconvenience to various organisations. As to whether such a feeling should be allowed to have any bearing on disarmament action is a question which requires a very clear view of the premises of this argument. If we assume that disarmament is a relatively unimportant matter, then such suggestions can be regarded as impracticable and distasteful in the extreme ; but if we take the view that we must absolutely do everything within reason and in our power to prevent the outbreak of another world war,

and that disarmament is of the greatest importance, then the difficulty and inconvenience of such measures becomes a negligible factor.

We can easily focus this aspect of the matter by considering what our view would be if world conditions had reached such a point that we were on the verge of another catastrophe similar to that of 1914. Under such conditions we would not hesitate to check any step, however inconvenient, which appeared able to promote the event. Now, if that would be our view under those conditions, when it would be too late to take useful action, there is only one logical conclusion, which is that it should be our view at any other time, when such action might be of value. If we are trying to take steps to check a certain development, it is absolutely irrational and insupportable to modify the intensity of our actions by the supposed remoteness of the emergency towards which those actions would be directed if the emergency occurred. This process, of course, operates in the small events of daily life, but, carried into a world issue of primary importance, it may be fatal.

We could not have any better example of the divergent views held by prominent scientists on this matter, and of the absence of any general well-grounded policy or viewpoint, than the two references which I have picked up at random from my files. *Die Chemische Industrie*, the well-known German scientific periodical, commenting on poison-gas in 1921, wrote, " It has happened that almost at the same time two important English chemists have given their opinion on the use of poison-gas in war. At the opening of the annual meeting of the British Association at Edinburgh, it was stated by the president, Sir Edward Thorpe, that during the last war the Germans used eighteen different kinds of poison-gas, which made reprisals unavoidable, so that for three years the chemical laboratories of the civilised world strove to produce the most terrible and lethal compounds known to science. Professor Thorpe described this as a disgrace to humanity and science. His colleague, Sir William Pope, on the other hand, spoke some days previously at Montreal on the same subject, and told his audience that by the end of the war the Allies possessed mustard gas in such quantities that the Germans were beaten. At the same time a new poison-gas was being manufactured, against which no mask offered protection, and which was so strong that it sufficed to stop the enemy even at a dilution of one part in five million parts of air. The use of poison-gases had been made generally legitimate, and was actually more humane than

modern explosives, and in future wars the chemical weapon would alone be decisive. These two conceptions have now led to a controversy in the English Press, in which chemists are divided about equally." The article goes on to describe the horrors of the future chemical war, and concludes, "Against these dangers, which cannot be thought to be fully removed, there is only one safe protection ; the maintenance of peace."

At about the same time we find in *The Times* an account of the speech by Professor Leonard Bairdstow, the retiring president of the National Union of Scientific Workers : "During the year, he proceeded, an attempt had been made by the War Office to encroach on the very limited resources of the Universities. It had been suggested that professors should have charge of secret laboratories working on the preparation of life-destroying chemicals. As a union they were not connected with the rights or wrongs of chemical warfare ; their objection to the proposal was primarily to the idea of the War Office attaching parts of their Universities to itself. The introduction of secret research into the Universities cut at the root of the freedom to pass on knowledge, which freedom was the basis of sound education as well as a great privilege, and should be defended with all their strength. A resolution was passed urging the Council of the League of Nations 'to form a section, composed of representative scientific workers, to study, confer, and report on all matters on which scientific advice can appropriately be given.'"

All these gentlemen were approaching the problem from different angles ; they would probably all agree that the solution was to be found in the maintenance of peace ; but so far it has not been realised that this very objective is dependent upon the resolving of these different views into one definite and agreed policy, formulated and substantially maintained under the authority of world science, which, in fact, is not aloof, outside the problem, but most positively within it.

I therefore want to draw attention to the fact that science as a whole is at sea as regards its attitude towards armament and disarmament. A perusal of some of the presidential and other sectional addresses before the British Association since the war provides a very good illustration. One finds prominent chemists such as Sir Edward Thorpe denouncing chemical warfare in no mild terms, whereas others have come forward with contributions to its study as though it were a perfectly normal field for the scientist's activities, as, indeed, it is in a nation with only one

policy of intensive armament development. Prominent physiologists will put forward a cold-blooded defence of this form of war, and other scientists will break out into a hot emotional attack against it. Both viewpoints, in my opinion, are insufficient. Science as a whole wants first to acquire some definite attitude towards this matter consistent with international and national policy. That is the first thing. The second is admittedly more difficult—the need of some form of organisation to give effect to the policy adopted, or, to be more exact, to prevent as far as possible the overstepping of the boundaries and the restrictions laid down.

The control of unofficial chemical warfare research is part of a very big question. Disarmament can only have bearing on two kinds of armament—those already in existence, and new forms not yet discovered. What attitude is to be adopted regarding the latter under a world policy of graded disarmament? The old forms of armament lend themselves to relatively simple disarmament arrangements, based on considerations of establishments, numbers, and tonnage, but the newer forms as we know them are less susceptible to such treatment. It follows that if and as new types develop and increase in number, so their arrival will disturb disarmament arrangements relating to the older forms. Clearly the simplest solution for disarmament is to check the development of new weapons. This is the logical conclusion, but is it a foolish one? What reasons could be urged to encourage or not to discourage the development of new weapons?

It might, and it no doubt will be said, that this would represent interference with scientific progress in two respects. More often than not the indirect results of scientific work are more important than the immediate objective. To submerge any scientific investigation aimed at a definite technical objective may mean stifling some important theoretical outcome or other practical applications which might not be of a warlike nature, but which might be intensely useful for peace. This must at once be admitted and the issue becomes clear. Do we desire, in the interests of peace, to take the risk of stifling the incidental peaceful applications or increase in knowledge arising from work on a new weapon? It all depends on the importance which we attach to disarmament and to the prevention of another world war. If we attach very great importance to this, there is no doubt that we can readily sacrifice any of these possible incidental advantages of investigations on new weapons. There is also this to be said—that if the work is going on, and time, money, and brains are being expended

on military devices, we are just as likely, in fact more likely, to gain results of value in peaceful industry and science if the same time, money, and brains are deliberately diverted to peaceful objectives.

It could be said with truth that a great deal of important results accrued from the work done during war on the gas mask. The vast amount of work on the absorptive capacity and properties of various forms of charcoal was undoubtedly of great benefit later in industry, and has found important and extensive application in processes for gas purification, separation of mixtures, etc., but there is really no reason why these results could not have been achieved, and with the expenditure of less time and money, by a direct attack on the problem, disregarding its bearing on gas warfare. Physico-chemical work on the absorption of chlorpicrin by charcoal would probably have had more, and certainly at least as much, incidence on industry had the researchers been handling industrial instead of war gases. Again, it is true that the work on mustard gas threw a great deal of light on chemical reactions, on the chemical production of ethylene by catalytic decomposition in electric furnaces, on the production of sulphur chloride, on the manufacture of the derivatives of glycol, which are of such interest in the organic chemical industry, notably for dyestuffs and pharmaceuticals. At the same time it can also be argued—indeed, strongly—that if this work had been done with purely peacetime objectives with no attention to the military end-point, mustard gas, the same research facilities would have been calculated to produce even more valuable results, as they would have been free of the mustard gas casualties, of all the precautions which had to be taken in handling that substance, and of the limits imposed by its very dangerous nature.

It may also be argued that the world wants the newer weapons because of some advantage which they possess as contrasted with the old weapons. For instance, it has been said that chemical warfare is more humane, and it may be said that concentration on new weapons may lead us to a position in which one nation can impose its will upon another with no physical suffering of any sort. Therefore, although we disagree that up to date the newer weapons have proved more humane, we must admit that they might be so in the future. We have already dealt with this subject, and the crux of the matter is that there is no guarantee whatsoever that such types would evolve, or, if they did, that they would be chosen in preference to others. In any case, this argument

presupposes that we are admitting war as a legitimate international activity; it ignores the objective of disarmament, and side-tracks the real issue. Mankind in the past has not shown any special tendency to refrain from causing physical suffering in war, and if weapons are to be consciously developed in this direction it implies a change in moral outlook, but the same tendency which might cause us to seek for more humane weapons would undoubtedly cause us to adopt a much more drastic policy to avoid war altogether. In such a case, instead of wasting time trying to devise painless weapons, the only logical conclusion is to devote the same energy towards making new weapons unnecessary—that is, towards disarmament.

It is difficult to find any reasoned grounds, therefore, to encourage the development of new weapons, and, as they introduce such a big element of instability in any disarmament scheme, we are compelled to consider what steps can be taken to check such development, based on general agreement that it is undesirable. This brings us at once to the very urgent problem of checking the development of any new chemical weapons, and back to our problem of checking private research in the new agencies.

A PRACTICAL STEP

If we regard the League of Nations as the working centre of international peace organisation, with America co-operating or an eventual member, there is one great practical step which should be taken, and it is inconceivable why it has not yet been done. The organisation of the League shows quite clearly that whenever it approaches a problem or group of problems of major importance, such as normal armament, world tariffs, or labour organisation, it creates a permanent element of organisation within itself, with all the necessary external linkages. This is required to-day to cope with the problem of organised or casual scientific contributions to new types of armament, and of armament development in general. In all other cases this step has occurred in the normal organisation or enlargement of the League, which has not waited passively for private interests to compel attention to a general problem in which they are interested. Indeed, such private interests have rarely had a general or organised consciousness of the existence of the problem. On the contrary, in some cases, such as the drug traffic, the parties most alive to the issue and aware of its technical facts would obviously

never have taken any step to invite an examination of their position. But the case of science and warfare is quite different, for in the past it has only been with the greatest reluctance that the best and noblest elements in national or world science have intruded upon what we may call political matters for want of a better term. They can only be said to have leapt into the field of policy and organisation on such occasions as the great stress of national danger in the face of a human enemy or epidemics of disease. The murmurings of an independent writer, or of many, are not likely to move science to the recognition of this problem and the necessary action, but she could not fail to respond to an appeal from such an organisation as the League of Nations to examine and move in this vital problem of disarmament.

It would be for a representative scientific body so created to advise on actual measures to give effect to international policy as to research on armament type, whether the agreed requirements were to stifle or to proceed with such work on a limited scale. In so far as the measures proposed have incidence upon scientific institutions, patent legislation, and other factors which govern the means and rewards of armament investigations, it would be necessary to obtain equivalence of effect in different countries under different systems, and it is because any detailed scheme would meet with the most violent and varied criticism unless it had been through this central and authoritative process of unification that I do not propose to subject the broad issue to any weakness or diffusion by bringing forward a whole range of practical suggestions.

THE FREAK INVENTION

We have thus reached the position in theory in which the technical mind most likely to contribute to armament development is subjected, through organisations and by the creation of a guiding background, to a measure of disarmament. The net result is to check armament contributions from a great number of possible contributors to an extent measured by the thoroughness and efficiency of the steps taken and the schemes adopted. But it can always be claimed that outside any such scheme contributions are possible, the origin of which could never have been foreseen. Technical advances are not always and only made by orthodox scientists, engineers, and technical people. Now and again valuable results emerge from untrained minds working

along purely empirical lines by a thought process which would be entirely discredited but for the unexpected result. The various military inventions of the father, Immanuel Nobel, are just as representative of this type of development as those of his son, Alfred, were characteristic of the more systematic and scientific process. The more or less empirical invention of Portland cement by Asplin provides another example. Reviewing the history of any broad field of science, modern industry, or armament, it must be admitted that this type of contribution to development has occurred, but to-day it represents a very feeble proportion of the total. It would not be a very serious risk to ignore it.

But if, instead of the present position, with the nations solemnly meeting to reduce normal armament, there were agreement to restrict the armament race in type as well as in quantity, it would of necessity involve some measure which would automatically cope with the theoretical difficulty, introduced above, of the "freak" invention. Nations agreeing to cease the evolution of new armament types would have to agree on certain measures for dealing with the usual processes by which such evolution occurs. This would have to include consideration of the case of the private inventor offering his wares to a Government, which would be his only market. It could be made illegal to offer any war invention to any Government department or servant, just as it is illegal to offer a bribe. There would be doubtful cases, which at once indicates the need of some central organisation to receive any such offers. The whole matter could be made part of the organisation being built up as to the trade in arms, as it would at once become a logical matter to include in that scope the trade in arms processes.

THE INTERMEDIATE STAGE

We can imagine that the birth of a new agency of war or a military invention has escaped the net of prohibitive measures, or we can take the view, which I have taken, that rational disarmament must have the widest scope, and must therefore deal with all the growth periods of a weapon. We have therefore to consider what occurs after the pure research or discovery stage. Experience of the whole field of technical development allows us to draw one broad conclusion ; it is extraordinarily rare that any invention leaps from discovery to steady production without a laborious period of work on a semi-industrial scale, which often extends over long periods.

In the chemical field, the manufacture of mustard gas provides a good example. Reviewing the processes developed on both sides, there was a period varying from six to eighteen months devoted to this work. Expenditure was over a million, and probably nearer five million pounds. In this period of evolution of a manufacturing process the British effort was by far the most costly, and the German the least. France was intermediate, and America, being able to benefit by the errors of her Allies, and also because her efforts were very ambitious and far-seeing, should hardly be brought into the comparison. A host of problems faced these countries once the manufacturing decision was reached.

I remember visiting factory after factory in France, where devoted workers were disfiguring their bodies and ruining their health working on baby plants producing experimental quantities of mustard gas, facing new problems on the production of those chemicals which reacted to produce the deadly fluid. There was the continuous catalytic manufacture of the gas ethylene, and the evolving of a continuous process which would work for months without compelling the worker to handle the harmful end-product. In one case this was achieved to such an extent that the raw materials were introduced at one end and the mustard gas came out at the other, feeding a pipe line, itself distributing to filling machines in a distant filling station. Apart from breakdowns, there was no contact with mustard gas, and it simply emerged in the finished shell. Here the time, casualties, and expense, all considerable, were incurred in evolving a continuous system with pressures and flows nicely adjusted, and choice of suitable material for the plant in order to ensure smooth running with minimum harm to the workers.

In England, where a different process was employed at first, the standardisation of sulphur chloride arose as an obstacle, and the disposal of tons of dangerous material which had taken a wrong turning in the process became a problem.

Gas-shell filling went through the same phases of development before it became a smooth-running bulk manufacturing operation. I remember closely following all the efforts made in Allied countries, and seeing curiously garbed workers testing new machines in old forts on the outskirts of Paris, in soap works, and in brand-new filling stations erected a year before their processes were perfected. The development stages were so dangerous that hardy veterans from the French front were brought to the rear and given various privileges—special leave periods, diet, and

treatment—in relation to the risks they were taking. In all kinds of factories, scent works on the Seine, soap works on the Rhone, private sheds and laboratories, half-scale plant could be seen evolving through a patient long-time process with the greatest urgency behind it, even on the simpler war chemicals such as the lachrymators and phosgene, and there were many personal tragedies and sacrifices.

On the mechanical side of armament this process has to be passed through, but is usually much less dangerous, although the amazing series of loss of life in the evolution of the submarine constitutes a notable exception. Even in that extraordinary case of the Maxim gun, whose life period of developments was probably shorter than any other known weapon, Maxim spent several months in his small workshops in Hatton Garden, making and testing his models and redesigning the different parts to get the finest equilibrium in the machine as a whole. It would be expected, and is generally but not universally true, that the smaller types of new armament would have shorter periods of development between the idea and manufacture. It was more than a year before the end of the war that the belligerents began to evolve gas bombs for aircraft. The fact that these were never used on any scale is not only due to hesitation to employ them, but to the technical difficulties in evolving efficient types. The problems of adequate strength of container with minimum weight and minimum thickness of wall to give maximum gas content involved new problems and innumerable tests, not only as regards the metal on the metallurgical side, but in the methods of its shaping. The nature, position, and construction of bursting charges in relation to impact and to maximum efficiency of diffusion were all difficult problems.

If manufacture were embarked upon without adequate attention to development and design, results were sometimes fatal. Personal recollections of the front line in the Loos battle leave no doubt on this point. A few minutes before zero, the moment of attack, the metallic gas tubes were connected and nozzles lifted over the parapet. Great clouds of chlorine came flooding into the gas emplacements, pouring out of faults in the piping, and putting many of our own people out of action. Solemn discussions took place in company headquarters behind the line a few hours later as to whether and where this ghastly responsibility could be placed. We are not here blaming any manufacturers. The matter was speedily put right by the adoption of new emission designs

which would no doubt have been available in the first place had there been opportunity for thorough testing and development in home stations. Again, we have some idea of the half-scale development of heavy armament from our references to Krupp. Any uncertainty or change of design in, say, the heavier parts of a big gun must involve very long periods; such items may spend months in the hands of draughtsmen and planning departments; the processes of forging, tempering, cooling, shaping, and many others themselves control the time factor. There is no possibility of rapid adjustment.

The military side of this half-scale development is closely linked up with the purely technical. When a new device passes through two or three stages of design, it is more often than not due to results obtained by testing each under military conditions and control. This brings back all kinds of recollections of military tests on new war devices, some of which were so inadequate under test, although they had received the best technical thought, that they were simply abandoned, and the particular time and effort of development wasted. I call to mind tests on Salisbury Plain with a carefully designed apparatus to shoot out a spray of poison-gas from a container strapped on to the soldier. Liquid chlorpicrin was employed, which, besides being very deadly, has a fiercely painful effect in very low concentrations. The operator had to be rescued from the trench system in which he was demonstrating round traverses, and most of those following the tests faithfully and closely were temporarily put out of action. The device was never employed in war.

On the other hand, one remembers most successful tests on the French grounds at Satory, near Versailles, on new designs of the small French flame projector. The idea towards which the Germans and British had evolved was a huge, stationary projector comprising pressure, vast storage, and complicated nozzle arrangements, which was usually employed against enemy strong points in great attacks. Perhaps some remote reader will remember visiting Bronfay farm, on the last hill behind the line at Carnoy, a day or so before the great Somme offensive. The farmyard, consistently under shell fire, was a curious sight, full of the large and multitudinous components of a huge flame projector which we assisted to carry into the line for installation. Promptly at zero hour a terrific flame emerged and covered a German strong point, which it was thought might hold up the advance opposite Montauban village. Although the moral effect was undoubtedly

great at first, its limited and local destructive powers may be judged by the fact that this same strong point was a consistent source of worry to parties moving past it towards the German trenches a day later. Germans left in the strong point unharmed were doing their best to snipe the British relieving forces. But the French had concentrated on a much smaller portable form, which the soldier carried, and from which he could get a large number of shoots with a range of twenty or thirty yards. The tests at Satory proved the design, military feasibility, and efficiency of their weapon, which was used later on a large scale in clearing dugouts in captured trench lines.

From these brief descriptions it will be seen that, even with a mechanical device, the development period, given maximum facilities, must still be a long one, combining, as it does, the most important thorough collaboration with purely military tests. It is a phase of armament development which requires elaborate, expensive, properly organised, and difficulty concealed facilities.

We thus see the nature of this intermediate or second stage in the growth of a weapon, and, having identified the main characteristics, we naturally ask whether they suggest any measures which might be helpful in the prevention of such development. The latter, as we have seen, consists broadly of semi-industrial work such as might accompany the development of a process having no military bearing, and of the larger-scale military investigation and testing which must always precede the adoption and standardisation of a new contribution to armament. We are not attempting to cover the minutest detail of our subject, we fully appreciate that any classification will leave exceptions, but to be constructive we must classify.

Broadly, then, the former or non-military type of development can be fostered in three ways : by official establishments such as arsenals—witness the development of mustard gas processes and of new lachrymator or blinding chemicals at Edgewood arsenal ; by armament manufacturers or private firms—witness the development of Maxim gun production by Vickers at Crayford, or again the mustard gas processes by Levinstein Ltd. in England, or the I.G. in Germany ; and by individuals—witness the efforts at different times of the brothers Nobel in their evolution of modern high explosive prior to actual commercialisation.

OFFICIAL HALF-SCALE WORK

The problem is a simple one for a Government honouring a covenant to refrain from evolving new types of armament, either entirely, or within certain limits of technical standards and specifications. Official finance in budgets or other forms of grants can be strictly limited to manufacture of agreed quantities of known and specified types of weapons. Facilities for research and investigation in terms of money, equipment, or personnel can be eliminated or limited in a manner consistent with the covenant.

To-day, in many departments of the three arms, military, naval, and air, in all the great countries, the armament race in type of weapon is going on; new arms are labouring through the adolescent stage. Anyone who cares to examine the information available, without reference to any inside or secret knowledge, must realise that although the world may be marking time in the old form of armament race, which was mainly a question of quantity of known types, and although some effort is being made to replace competition by equilibrium in that matter, a new armament race has supplanted the old. It is quietly going on without comment, largely because it is a province with which the world is not acquainted. If a great war were to break out to-day on the basis of the armament types which have evolved since 1918, or during the war, and were not used, so much has been done already in a period of ten years, during which perhaps the greatest characteristic has been the peace effort, that the face and nature of war would be changed. We should have, as we know, a much higher degree of mechanisation, vast numbers of tanks, moving on the average at speeds five and six times greater than those we witnessed. Machine-gun development, with its rain of death, would be vastly intensified, both in use from tank and air. The capacity to kill and mutilate civilians, women, and children would be hundreds of times as great as it was. These basic changes in the nature of war have been going on at a time when the world in full conference has been considering the fundamentals of stopping it, and, broadly speaking, we have been blind to what is probably the most vital practical and immediate issue in this great matter.

It is as though some abstruse field of medical investigation were quietly pursued with growing volume, and with growing incidence on public life, without any general knowledge that vital issues touching the liberties and behaviour of the ordinary man were

being created, and would have to be faced by a world which, had it been aware of the facts at an early stage, would at least have considered whether that particular medical development was socially desirable. For instance, there is a field of medical science which studies the relationships between glands and certain secretions and human personality. It is not impossible, nor scientifically incredible, that the growing volume, intensity, and success of these investigations might give mankind some extraordinary power in the modification and control of the personality and behaviour of his fellow-creatures. It is at least a fair view to take that the full development of such a power by medical science would be unwise, unless it were accompanied by an intelligent appreciation of its possibilities by the mass of human creatures who by governing would wield, or as subjects would endure, the results of such work. In the ordinary way, in the medical, industrial, and political worlds, new activities of this sort receive publicity, and are ventilated and criticised long before they become so unwieldy as to compel a crisis, but place such a development behind a veil of the greatest secrecy, maintained by law under the direst penalties, and you get the conditions of the armament race in new types. Ignoring for the moment the aspect of national competition, domination, and suspicion, and viewing this simply from the point of view of the individual endeavouring to live in a peaceful and ordered world, we find what is really an extraordinary situation. Behind closed doors, removed from the sane influence of public opinion, not even understood by the appointed representatives of the people, you have an activity, publicly financed, which, unknown and uncontrolled, may quite easily by itself develop a crisis and produce a catastrophe as great as, or greater than, that of the last war.

I am again guilty of digressing, but conclude in this matter as follows. If we wish to substitute stabilisation and security under international arrangements for the unknown dangers of unimpeded secret national development, then the problem of official work and establishments presents no difficulty.

PRIVATE HALF-SCALE WORK

The question of such half-scale development by private armament firms is really linked up with the whole matter of the private manufacture of arms. Logically the position of maximum

disarmament does not admit the existence of such firms with their present freedom. There can be no other rational conclusion. A situation in which Government establishments faithfully refrained from arms development and private firms were under no restrictions would be purely Gilbertian. Once admit a free commercial market for arms, admit therefore rich financial rewards for new and deadly types, and you effectively torpedo the ship of peace, if peace mean disarmament. Private firms must be submitted to exactly the same restrictions as Government arsenals in any disarmament measure, and if this is done the category for the purposes of our argument ceases to exist.

We come to the last class, the private inventor, carrying forward his invention in some workshop just as Maxim did in Hatton Garden, or the brothers Nobel in their small chemical plants. No systematic practicable system of inspection could guarantee to detect all such cases if the parties concerned were attempting to evade discovery. At some time or other disarmament has got to say whether it is right and proper for a gifted individual to employ his talents and make his livelihood or fortune in pursuing the development of newly invented weapons. To-day an inventor with a bright idea for a new machine-gun, or a poison-gas, can take a factory, employ labour, legally protect his invention, perfect it and its manufacturing processes, and sell it for a million pounds, if he can, to a Government, member of the League of Nations, and wedded to disarmament as a continuous policy above all parties. He can get a knighthood or peerage and the acclamations of his fellow-creatures, whose lives or whose sons' lives he may perhaps unwittingly be exposing to the gravest danger. Apart from the individual conscience, this is an attractive and remunerative career. If, on the other hand, all forms of private armament development were illegal, no patents were granted, except to Governments, no private legal protection were possible, no rewards, material or otherwise, were obtainable, how many new weapons would emerge during the next fifty years? The machine-gun and the products of Krupp would never have seen the light of day under such conditions. This is no criticism of past or present inventors engaged on armament, but of ourselves and of the times for allowing a situation to exist whose absurdities and inconsistencies can hardly be matched in any other field of international affairs.

The military proving of a new feature of armament presents a simpler problem. The weapon cannot mature without passing

through a definite programme in some proving-ground or testing-station. These range from vast terrains, such as the Krupp artillery ground at Meppen; Edgewood Arsenal, in America, with its three thousand four hundred acres, thirty miles of rail-track, which was vast enough to house and occupy ten thousand men during the war, although not all engaged on testing, but mainly on manufacture, construction, and training; Porton, on Salisbury Plain; to smaller installations for bomb and explosives testing. The technical nature of the work and the precautions necessary, quite apart from secrecy, necessitate large stations amply equipped and staffed, even for the short-range effects. It is impossible to conceal such places, entirely to hide their activities. It is impossible to make any real progress in developing new weapons without them. Apart from certain exceptions mentioned below, there is no need to maintain them in a disarmed state. Here is a critical step in armament progress which could be controlled by agreement with considerable ease and effective result.

THE DEFENSIVE TYPE

It is obvious that all such facilities cannot be suppressed, and it is a usual form of argument that, as you must admit some such work, so it is hopeless to expect to get a genuine limitation in this matter; but that again is beside the point if we view disarmament in this field as a serious and urgent matter. The case cannot be disposed of in this way unless it be treated rationally and scientifically by considering what those essential exceptions must be. There is, in the case of chemical warfare, the well-known example of the gas mask. Whatever we may do with regard to retarding or stopping the development of new gases, the fact remains that some very potent forms are already standardised in the equipment of war. Therefore, while any armies or armaments, or types of hostilities, have international sanction there must be a form of gas defence.

The interesting question arises as to what policy regarding the gas mask is most consistent with a stable peace, in the organisation of which we are employing armament reduction and equilibrium, based on essential defence as against unlimited offence. It is perfectly clear that under rational disarmament, including the chemical field, the disparities which existed at the end of the Great War between the various combatants, and also between

the latter as a group and the non-combatants, will disappear. The tendency was already illustrated in my own mind at the end of the war by the transparent efforts of a friendly Japanese attachê to collect every possible scrap of information by the way of documents and conversations on gas warfare which were properly and officially available to him. Although the combatant nations possess an inherent advantage of the experience of bulk use of chemical warfare, the differences, when all aspects are considered, will tend to disappear.

But this approach to equilibrium in type of chemical armament is not an element of stability by itself. It depends upon whether the disparity is also reduced in the matter of gas defence, which is essentially the gas mask. A country relatively unprotected against enemy gas cannot restore the equilibrium or lose the basic disadvantage merely through being in a position to reply with the same gases against the enemy who is efficiently protected. The logic of the situation, so far as disarmament is concerned, demands movement towards a position in which all countries have maximum protection, so that differences are reduced, the general efficiency of the new weapon is crippled, and its special dangers as compared with other weapons in the matter of a decisive surprise or war initiative are removed. This means, in plain language, that all the great nations, if they adopted a rational disarmament policy as regards chemical warfare, would standardise on the same gas mask. Admitted, there are national peculiarities which would perhaps impose differences in shape or design, but they would at least be given an opportunity of examining all types so as to choose the best, and, as the subject is strictly technical, governed by rather exact standards, it is fair to assume that the essential protective features of national masks would be the same.

Further, as it would undoubtedly be claimed that no national mask had yet reached the position of maximum efficiency against the known gases, it is probable that it would be advisable not to call a halt yet in gas mask development. This at once implies the admission of a certain amount of the kind of work the general restriction of which we are discussing. But, again, to be strictly consistent with disarmament as against armament standards, such work should have a limited objective of maximum efficiency against known types, and should not include an indefinite and prolonged investigation into defence against types which are only yet on the armament horizon, or which are secrets of the

future. This would only re-open the whole problem of unlimited development.

If these principles are correct, a very simple plan would meet the situation. There would be a time limit agreed as to present organised national effort, and the nations would agree a definite technical protective objective ; the matter would be reviewed centrally at the end of this period with the idea of terminating or still further limiting national work. Eventually a standard would be agreed and adopted, and the only further changes which need to be introduced would be any improvements which arose incidentally from peacetime work on protection against industrial and mine gases. This, of course, introduces the whole question of the standardisation of national weapons as to type, and not only as to quantity, which is discussed elsewhere.

I have no doubt that in other fields of armament there are other similar items which specialists would bring forward as being essential exceptions in the restriction or elimination of this phase of arms development.

LARGE-SCALE WORK

We have now brought the new armament type to a position from which two further forms of large-scale work are required before supplies can be considered. This final step gives the weapon maturity in the sense of leaving adolescence, but it does not, of course, impart to it the ripe experience of use in war. It represents the maximum distance to which the weapon can be taken in the absence of war, the development of a high state of armament potential which can only be increased by the existence of large and immediately available supplies. Let us take in turn manufacture and military application.

All the points which could be foreseen surrounding the manufacturing process have now been explored and proved to the utmost, within the limits of investigations on an intermediate scale. In the case of a chemical, a unit will have been constructed and operated to satisfy the chemical, physical, and engineering requirements of the sequence of processes, and special precautions will have been worked out to protect the worker from dangerous products and waste. With a mechanical device, such as a new machine-gun or bomb, dies, jigs, and other accessories related to design will have been made. If the new weapon requires

a departure from standard engineering appliances, a model will have been produced of the machine in question.

The next step is to ensure the feasibility of supply, when required later, by cutting out all difficulties and elements of doubt in the transfer from half-scale to a bulk unit operation. It means the actual building up of one unit of production of such industrial size that further bulk supplies simply involve its multiplication. This kind of work requires a factory, which, again, will either be under official control or in private hands. Thus, for example, it is reasonable to assume that units of this sort on new war chemicals, if they exist at all, would in England and America exist in Government establishments, whereas for heavy armament, such as guns or tanks, general knowledge would place such units in private hands in all the great countries.

It must be obvious that if any potent new weapon has been brought as far as this stage since the war by any country, thus possessing proved units for production, then we are faced with the existence of factors in the evolution of armament, and not simply with theories and possibilities, which are just as inconsistent with the logical needs of disarmament as the great disparity in naval and land armament which the world is striving to remove with some success. One can well imagine that such a situation exists to-day as a result of national efforts since the war. We have seen the reference from a great armament firm to the development of experimental army equipments ready to feed the world's markets, and we know that if they include tanks they will be new types, vastly different from the old. We have heard of the new machine-gun-rifle, the Pedersen gun, and it would be a fair assumption that some nations have proceeded still further in divergence from previous types. It is at least likely that some of the Great Powers have brought the new arsenic compounds to the stage of development which we are discussing, and Lewisite, or still more potent forms, may even now be only removed by one small step from the possibility of supply and use by a country—America—whose traditions and tendencies would be violently against it. It is amazing to consider this situation silently developing in countries to whose policy and people the logical outcome of use and application to human beings would be in the highest degree repugnant.

This is in no sense an aimless outcry against these activities, and it entirely ignores the moral or emotional background. As I have said, we may again be caught up in a process of still further

armament development, and foster it in a manner consistent with national ideals. But it is a cold attempt to show the existence and implications of this problem and to ask whether there is not some better way of dealing with it than simply to ignore it.

Maturity of the manufacturing process does not complete the weapon, for it has to be perfected in the direction of military application as far as the absence of war will allow. Prior to the Great War, military science had not paid systematic attention to this question of large-scale tests. Germany had led the way, under the initiative of Krupp, in the matter of artillery proving-grounds, and we have seen the arrival of Dulmen and Meppen. The latter stimulated similar organisations in other countries, but it was not until the Great War that the general impetus for such work arose. Then the rapid alternation of threat and counter-threat in armament design and type simply compelled organisation on these lines, and we saw the large-scale and final testing of gas, Stokes mortars, smoke, bombs, new machine-guns, flame-projectors, and all kinds of weapons and defensive appliances on really efficient testing-grounds organised by the most thorough co-operation of military specialists and pure and applied science, ranging from great territories, such as Edgewood Arsenal and Porton, capable of staging miniature battles with the new war agencies, down to smaller grounds, such as Satory in France, and others in Italy. These establishments supported large permanent staffs of specialists and operators, and were equipped with intricate scientific arrangements for measurement and control. Many of these have survived, and it is not generally known what they have produced since the war.

There seems little doubt that in chemical warfare much of the work has been purely defensive on protection and gas masks, rather than towards aggression and more terrible types, this being consistent with the prohibition of gas warfare, and with the expectant attitude of some military departments, including almost certainly the British, that some rational measure of disarmament in this matter would eventually emerge to which they could safely subscribe. Indeed, so much is this so that criticism, if applicable at all, is not so much directed towards the activity of armament departments as it is towards the absence of constructive disarmament schemes able to justify national inactivity on armament development. But this is probably only true of the chemical field, being related to the positive but nebulous world policy of checking chemical warfare, and its absence in other fields is related in a

parallel way to the absence of any international opinion and viewpoint on the evolution of new armament types in general, whether they be chemical or otherwise.

In any case, if and when it be considered essential in the interests of peace to stabilise the movement in armament type, a consideration of this question of final military proving or testing would be critical. The establishments are usually vast, they cannot in any case be concealed, and practically every important new advance in armament must pass through them. In the limit of maximum disarmament and minimum armament their use would be very greatly restricted, almost entirely eliminated, as, for example, in the chemical case, to certain agreed defence. The Great Powers would certainly not need a fraction of the facilities which they now possess.

We have now dealt with and fairly described the characteristics of the growth of a new weapon, and, to say the least, it must be abundantly clear that a world wishing to incorporate equilibrium and stabilisation of armament type in its peace measures is not only faced with a series of specific problems which can be defined, but it need not stand helpless before them.

EXISTING NEW AGENCIES

At the beginning of this chapter it was pointed out that the disarmament problem for a new agency of war which had not yet passed through the major part of its development process was not necessarily the same as for those which have come forward recently, but are already mature in the sense that they only need to be produced in quantity to become real weapons. This is the case, for example, with most of the known poison-gases, their combined use with aircraft, and the tank. Some of these agencies, such as the latter, can at once be classed, from the disarmament point of view, with normal armament, and our conclusions on that subject in a previous chapter would apply. The chief, and perhaps the only present, example of this new category is chemical warfare as already standardised. We therefore ask, having prohibited its use in war and wishing to assist that prohibition by practical measures in times of peace, what can be done? Obviously, any possible measures must relate to the production of the chemicals themselves and the devices with which they are associated to form weapons. The manufacturing and supply problem is not the same as for normal armament. In that case the problem is to maintain

but not overstep an agreed limitation, whereas in the present case it is to prevent or render difficult supplies of any sort.

Disarmament in this matter would require that there should be the maximum lag in the possibility of supplies should a nation decide to violate the prohibition at the outbreak of a war. This is a very simple matter to deal with so far as official production is concerned, for it simply means that, contrary to normal armament, there would be no national factories for prohibited weapons whatsoever, and the further precaution would be logical that there should be no standard official units to assist other factories in developing production. As regards private possibilities of production we come to the classical and oft-quoted case of the rapid conversion of chemical factories from peace to war products. This is again a different problem from the one relating to normal armament, because in that case it may well be that official and controlled national capacity may embody private factories, but here we have the problem of a Government honestly attempting to prevent private chemical firms from possessing any manufacturing capacity for poison-gas. In so far as this relates to products not required for peace, such as mustard gas, and, indeed, every known poison-gas except chlorine and phosgene, there is no problem, for the last thing the private chemical firms wish to do is to play with the manufacture of lethal chemicals, and it is an insult to their intelligence to suggest that they would do so in the face of national prohibition. The scope of the problem therefore diminishes, and resolves itself into those cases where the poison-gas is also a peaceful commodity.

We can almost deal with this entirely by considering chlorine and phosgene. The former, as an agent of war, was discredited almost from the moment of its use. Protective devices were very efficient against it, and other types were so much more effective. But it retained its importance as a raw material for most of the other poison-gases, and it serves the same purpose on a very large scale indeed for many peacetime chemicals. Its production could not possibly be eliminated or restricted. We have got to face the fact that in the modern world there will always be very large quantities of liquid chlorine available. If you wish, it is a risk which disarmament must take, but in view of the fact that it is not a weapon by itself, and that it requires special personnel, training, and appliances to have any bearing on fighting, it would be futile to argue, as has been done, that all other restrictive measures relating to the new agencies of war or to the chemical agencies are

rendered useless. Under a condition of real disarmament the case of liquid chlorine could be neglected.

There are one or two smaller exceptions in which the peace products of the chemical industry may coincide with those of war. Chlorpicrin may become a valuable insecticide, perfumery intermediates may readily be diverted to lachrymators, and we have already dealt with the case of azo-dyestuffs processes and intermediate products leading to organic arsenic compounds. But, as we have already pointed out in the latter connection, as soon as really large quantities were involved the rapid conversion of peacetime plants would no longer solve the military problem, and for disarmament the longer type of conversion lag would begin to operate.

Again, with regard to phosgene, the peacetime use is relatively very small, and, although it could be made in quantity, the other factors required to give it military value again predominate. They also really govern the situation as regards the general claim, which is true, that the conversion lag for these chemicals in the chemical industry is relatively short in relation to that of most other weapons. The more importance we attach to this latter point, so the need increases to give attention in disarmament to those other complementary factors which turn a chemical into a weapon. To most of these factors, such as containers, fuses, projectors, filling stations, and trained personnel, the facts of peacetime use and rapid conversion do not apply ; they would most of them be fostered by official establishments under rational disarmament, and in this particular field of war, where the whole weapon is prohibited, such establishments would not exist.

It is quite true that for disarmament this particular category of existing new agencies does not seem to admit such a water-tight solution, such satisfactory treatment, as other forms of armament. But the real question is how far such exceptions neutralise the total value of a reasoned comprehensive disarmament scheme, and within such limits there is no question of substantial danger, nor of a risk which should not readily be taken.

The general conclusion from the facts and considerations advanced in this chapter is that disarmament has been viewed too narrowly. It has dealt, so to speak, with a cross-section of the armament field at the time of consideration, and has been limited to one plane, a relatively static conception in two dimensions. But a third dimension must be added, due to the movement of armament with time, which tends later to distort the facts of

armament and the disarmament conclusions based on them at any previous period. We have either continually to adjust as time goes on, and the picture in the cross-section changes, or else take some bold step which tends to reduce, and finally eliminates, the results of time processes in this matter. In other words, the problem of evolution of armament type should logically be dealt with now, and not allowed to increase in magnitude and complexity so as to neutralise the value of present disarmament efforts which ignore it.

CHAPTER XI

SOME SPECIAL PROBLEMS

Combatants : The Private Manufacture of Combatants : Conscript Armies : Conscription and the Treaty of Versailles : Short Term Service : Combatant Conversion Lag : Types of Combatants : Officers' Training Corps : Infantry : Military Specialists : Armament Personnel : Aircraft : Military Uses : Gas and Aircraft : Military Aircraft : Aircraft Bombs : Commercial Aircraft : Incidental Disarmament Checks : Design and Technical Convertibility : Sighting, Bomb-Dropping, and Other Appliances : Personnel and Inspection

COMBATANTS

This is only a special problem in the sense that we have not dealt with it systematically in the previous chapters, nor can we do so here in any detail. But it is actually one of the broad fields and one of the basic problems of the whole subject of disarmament. It is important that we should examine the main principles relating to the limitation of combatants in a disarmament scheme, and note how the latter interlocks with the other aspects of armament control which we have examined.

We are on safe ground in starting from the fundamental requirement that the international allocation of the different elements of armament potential, no matter what they may be, must reasonably conform to the standard of limiting the rapid and adequate use of the striking force to special, agreed, and usually defensive objectives. It must be made very difficult indeed, if not impossible, for uncontrolled resources left out of the disarmament scheme to contribute to surprise and outlawed aggression in such a short time as to prejudice the successful operation of the processes of judicial settlement and arbitration. The magnitude and distribution of combatants must conform to such standards just as much as those other aspects of armament which we have considered.

THE PRIVATE MANUFACTURE OF COMBATANTS

It is curious that the world should hear so much about "the private manufacture of arms" and yet be so silent on the question of the manufacture of combatants. The danger is equally real,

and in fact to-day, with the world flooded with vast armament stocks from the recent war, the combatant problem is probably the greater in immediate importance. How far the private trade in combatants is a serious factor as distinct from the private manufacture or preparation is somewhat vague. In the Middle Ages, and even later, it was one of the biggest trades associated with war. Then they were called " hired mercenaries." In recent wars we have had, in the form of volunteers for foreign campaigns, if not the trade in combatants, yet a process giving essentially the same results, but usually with much finer motives. We need not dwell on this, for it would probably be safe to assume that to-day we need only contemplate the question of national combatants used for national purposes. It is a point, however, whether a rational and far-seeing disarmament treaty should rest on such an assumption, and whether it should not visualise and guard against the swelling of limited national forces by great numbers from other countries, either as genuine volunteers or inspired by less admirable motives. This certainly becomes a factor of practical importance when we realise the power of a cadre of first-class officers and specialists in converting an armed rabble into an efficient army. This process has been going on in varying degrees during the last few years in the internal strife of China. However, we will not probe the issues involved in this narrower problem, but must return to the broader one of general disarmament in relation to combatants.

We have here, just as with normal armament, a definite series of elements of potential, starting from some with a very long conversion lag and going right up to the spear-head of quick hostilities, the organised and rapidly mobilisable forces in arms. So far as we know, official disarmament discussions have taken note, and are still doing so, of the latter forces, the actual military establishments which are to be limited below certain levels in accordance with ratios to be agreed. Now it must be apparent that if agreed allocations of combatants are faithfully adhered to as regards the official armies and navies and air forces, then vast resources of unofficial combatants will become a threat to the stability of peace, whose magnitude will be measured by their numbers and by the conversion lag of their organisations. It is not in this case a question of production or manufacture in the same sense as with standard armament—say a heavy gun—but essentially of a state of organisation and of training related to armament capacity or equipment to feed such personnel.

This at once introduces a check on combatants which would always operate in a really comprehensive disarmament scheme dealing with armament or equipment. Absence of the latter imparts to the combatant substantially the same conversion lag as the armament which he lacks, however much he may be trained. This is not entirely true, because fully trained reserves are to a certain extent available for war for casualty replacement if we make the assumption that in some cases, as, for example, with artillery, the loss of the casualty does not necessarily imply the loss of the weapon. To-day this is probably a minor point, and the broad question before us is whether the control of combatants can be ignored under a condition of really thorough armament limitation. It cannot be ignored, and would be in the highest degree dangerous, for a variety of reasons.

In the first place, agreement as to combatants really provides the index or standard by which armament quantities and ratios will be governed in a disarmament scheme. Secondly, the business principle behind disarmament is one of the maximum safeguard, and to ignore the question of combatants would involve a very grave risk. It is true that it might be difficult to arm a vast excess with the maximum military efficiency as regards type of weapon and organisation, but, as we have seen, there are some elements or armament which are not subject to the maximum safeguard of conversion lag, and we can visualise the introduction of great disparity between national forces, even if the one possessing excess of combatants had to arm them with some type of weapon, such as a new chemical appliance. Again, in the permitted establishments it is fatal from the facts of military organisation that a high percentage of combatants, although carrying the usual small arms, are not employed in actual fighting, but on the mass of administrative and supply functions associated with bases and lines of communication. A vast excess of trained but unarmed combatants could certainly be employed to release large numbers of equipped men, and thus provide dangerous disparity. True, it would be right against military standards to employ unequipped but trained men behind battle zones, but they would no doubt find some defensive equipment from the non-standardised small arms manufactured in peace, and this risk might be taken for a time, if the possible result justified it, accompanied by feverish activity to supply the standard deficient equipment. Again, it would cut right into the integrity of the whole disarmament idea to have a scheme relating to armament with reservations as

to combatants. It would be inconceivable in a state of real disarmament to have two countries, each, say, with a hundred thousand agreed combatants, the one with no trained reserves and the other with a million. We should have a war spirit in one country and the opposite in the other, and, whatever arguments could be brought forward, nations would be uneasy, and justly so, under such conditions. Therefore the question of combatants in a disarmament scheme cannot be avoided, and the problem of " the manufacture of combatants " must be considered.

CONSCRIPT ARMIES

The great contrast arises of the almost immovable policy of national conscription in some countries and its absolute denial in others. I may be mistaken, but it does not appear that conscription as a principle or as a method of raising combatants has much to do with disarmament. If nations have solemnly agreed to possess, and only to possess, a certain number of combatants, it seems to be immaterial for disarmament as to how they raise those combatants, so long as the method adopted does not make available, indirectly, more trained men than the scheme permits.

The basic requirement of disarmament is that the armies permitted should be limited to a certain number of men who can be trained and organised to the highest pitch if the nations wish, but that there should be no others, beyond permitted reserves, able to step into their shoes, in virtue of specific training, more quickly than the slowest type, the untrained civilian.

The difficulty presented by conscription is related to present methods of operating this system rather than to the aspect of enforced military service versus voluntary recruiting. Modern conscription is a military machine turning out new groups of reserves at relatively short periods. The classes are called up in such a way as to ease the national burden and spread it as fairly as possible, which means giving the youth of a nation a year or two of training and then passing to another class. Suppose the interval is two years, then at the end of every such period a group of reserves is formed roughly equal in magnitude to the existing conscripted army. Thus in ten years, for example, by which time these reserves would still have value, they represent about five times as many combatants, whereas the permitted reserves in a reasoned disarmament scheme would be very much smaller.

It must be admitted that the same process must go on to a certain extent with any form of army by the natural exchange of newly recruited and service expired men. The factor which governs the disarmament position by creating reserves is the period of rotation. An army which renews itself, so to speak, in ten years will dilute the civil population with potential combatants to a much smaller extent than one of equivalent size which changes the bulk of its personnel in two years. The former is the present characteristic of the volunteer type of army such as the British, and the latter that of the Continental conscripted armies.

The well-known claims arise of the greater value of an army developing its training and remaining constant in personnel over long periods, as against another which only retains its identity of personnel for a short period. There can be no question that the best solution for disarmament is in terms of a uniform system. Here again there can be no doubt as to which one is more consistent with disarmament principles. The latter require the sharpest possible distinction between the limited combatants in the existing army and a civilian population from which they are drawn. Any system of conscription which gradually develops in the population an unlimited number of trained men departs from disarmament requirements. Under the latter, armies are required only for certain limited defensive and police duties; they are a fixed, small organisation in the service of the State, and in no sense should produce and constantly renew a general state of wide preparedness.

It will probably be very difficult to get nations to abandon conscription or to modify, so that their existing armies, by increased periods of rotation, have the characteristics of a fixed defensive force. Make the period of rotation really long and it becomes a great hardship for any small section of the population to be compelled to devote a large and the most important period of its life to military service. Under such conditions it is probable that peoples now wedded to conscription would revolt against it. It is undoubtedly true that the volunteer method of recruiting is the only one which would be found compatible with long periods of service.

Assuming that certain nations will not abandon conscription, what can be done to neutralise its adverse effect upon the rational distribution of reserves in a disarmament scheme? It has been suggested that quantities and distribution should be arranged so

that combatants in standing armies in non-conscription countries should be adjusted in quantity to compensate for the huge reserves produced by conscripted armies. But this is hardly practicable, for it would introduce great disparity between standing armies and thereby defeat the main practical objective of disarmament, equilibrium as to the striking force, and prevention of sudden attack. There is no real solution in terms of setting a ratio between organised combatants in one country and available reserves in another.

This is a vexed question, and the soundest solution would be to make the periods of rotation approximate in conscript and volunteer armies by increasing the former and decreasing the latter. Other modifications suggest themselves. There would be, and there actually are in conscript countries, a certain number of men who would volunteer to sign on for longer periods, and this renders a compromise possible, in which the maximum possible percentage of the agreed armies would be organised with maximum service periods, and the minimum with a shorter rotation.

In any case, it seems perfectly clear that to reach a real solution there will have to be give and take, and modification of both systems, to make them conform in quantity as to standing armies and reserves with the real needs and standards of disarmament.

CONSCRIPTION AND THE TREATY OF VERSAILLES

These points—rotation periods, their stabilising influence on reserves by increase of period, and the consequent need and desirability of voluntary recruiting—are well illustrated in the conditions applied to Germany by the Treaty of Versailles. In that Treaty, the system of conscription is abolished and substituted by volunteers ; officers must undertake to serve on the active list for twenty-five years, or until the age of forty-five. Other ranks must be recruited for not less than twelve years. Further, there are most exacting conditions regarding the annual percentages of combatants allowed to be discharged, the military training of discharged officers, and other rules designed to give maximum effect to the disarmament principles and requirements underlying the scheme. Again, be it noted, these measures were based on the best military opinion obtainable amongst the Allied and Associated Powers when faced with a disarmament objective.

SHORT TERM SERVICE

By contrast, it is of value shortly to examine the suggestion which has been made that, if conscription cannot be abolished or suitably modified to neutralise its harmful bearing on the question of reserves, then the period of rotation should be decreased as much as possible—say, as in one specific case, to six months. The argument which has been advanced in favour of this proposal is as follows. Disarmament is concerned with the prevention of successful surprise hostilities, and these could only occur during the first few months after an outbreak. The standing army of six months' life and training would be relatively inefficient for this type of attack, and the swollen reserves would not represent instability, because they could not be assimilated rapidly into the fighting army beyond the accepted ratio of, say, two and a half to three and a half of the existing forces. But this suggestion has serious weaknesses and dangers.

In the first place, such a quick rotation could not meet the needs of nations having extensive military duties of the police and colonial type. It is very doubtful whether such armies could perform their tasks. From the technical point of view, the combatants concerned might very well be quite unequal to the duties before them if called upon, and, indeed, in some cases they would barely have time during the six months to organise, equip, reach, and return from the distant scene of their activities. Again, their influence on Period A and its security through lack of sufficient time for intensive training does not, on close examination, appear to exercise the disarmament function which is claimed. Success in a sudden attack is a question of disparity between forces, of relative efficiency of different national armies, and, if the intensity of the striking force of each is reduced in a parallel way, we simply change the general level of efficiency, but do not introduce any greater stability thereby. Such a reduction only begins to introduce stability when it approaches the level of military efficiency of an untrained population. This would never be the case, even with a six months' period of rotation, for we should still have the basic distinction between equipped trained combatants, even though inadequately trained, and helpless civilians. Successful revolutions by minorities have been based on far less military difference between the opposing parties than this.

True, the disparity between the military value of reserves and

the striking force would be reduced, and the former in one country might be regarded as neutralising the striking value of the latter in another. But this consideration is weak because it ignores the impossibility rapidly to assimilate reserves beyond a certain ratio, and it side-tracks the vitally important point of strict limitation of such reserves.

This point is very important because, although we are mainly concerned with Period A, yet this is not the only consideration. We only concentrate on the initial period because it represents the maximum danger to peace. It would be grotesque to meet this danger by a method which entirely ignored the further disarmament requirement of crippling nations, so that if by any chance they struggled through Period A they would have enormous combatant facilities to pursue a great war on the 1914 scale. In other words, Period B, the time during which a nation could bring to bear its maximum facilities, is only less important because we assume that under a regime of disarmament its possibilities and dangers would be made remote. But the moment we take disarmament steps for another purpose related to Period A, which incidentally introduce instability into Period B, then the latter becomes the governing consideration in judging such measures.

Ease of evasion is another objection to the scheme of very short rotation periods in conscription. There would be strong temptation, and some possibility, of passing the same individuals repeatedly through the military machine and its short period of training, thus raising the combatant value of the limited army far above the assumed and agreed level.

It must also be remembered that this process of piling up reserves by short rotation periods under a system of conscription, or indeed in any recruiting system, has special significance and dangers with regard to the problem of the specialist combatant. The great reserves of men trained in the use of the newer weapons would cut deep into the otherwise formidable disarmament dual check of the limitation of specialist combatants coupled with that of the quantity and production of the special armament which they would use.

If we try to remove some of these disadvantages by increasing the period of rotation to one or two years, the type which is now standard in some conscript armies, we at once move into the position of minimum safety. We then introduce a factor contrary to all the principles of combatant disarmament—the steady

accumulation of vast reserves of really highly trained men. In other words, considering the problem of conscript armies in terms of a range of increasing periods of rotation, we can find no practicable zone of safety for disarmament in the short periods. The only sound solution is to be found in the long periods such as those enforced in the Treaty of Versailles.

COMBATANT CONVERSION LAG

What are the elements which go towards the manufacture of a combatant from a civilian, and which reduce the conversion lag of the latter? There are the two main elements of training: the individual use of arms, and military discipline in the sense of accustomed activity in military organisations. The third feature is the efficient organisation of such individuals into military units. With regard to such men not actually in the official army, there is the fourth point of their rapid availability through incorporation in a well-considered mobilisation scheme.

The period required to convert an untrained civilian into a trained soldier is a long one, even under the intensive conditions of an existing war, being fixed by different competent experts as between six and twelve months. But it is not simply a question of converting an individual, for we have to look at the problem from the point of view of training from rock bottom a sufficient number of combatants to change a defensive army in the disarmament sense into one capable of disturbing the peace of the world by sudden large-scale hostilities in defiance of covenants. We therefore have to add the further delays, which are substantial, in building up the complex living organisations in which masses of good individual soldiers become a good army or striking force. Taking this practical point of view, we have periods of conversion of hundreds of thousands of civilians nearer to two years than six months, and, looking at the problem as a whole, realising that these men must be armed, we have the conversion lag relating to equipment. There can therefore hardly be any doubt that a scheme of disarmament based upon the strict limitation of trained and organised combatants with honest and scrupulous attention to the question of pseudo-military organisations is likely to be effective, coupled, naturally, with armament limitation. It is, of course, realised that each nation has its own special methods of building up reserves, which would apply to permitted

reserves, and all kinds of exceptions will be claimed in disarmament negotiations. But our duty is to consider the logical requirements impartially, and the nearer the eventual solution in each case approximates to these the greater will be the security of the international position.

TYPES OF COMBATANTS

It is generally recognised that, as regards reserves, adequate cadre of officers and N.C.O.s are of vital importance for war, and, conversely, they must be equally so for disarmament. I am afraid that there is only one possible conclusion consistent with genuine disarmament, which is that, apart from the official organisations specially designed to train officers, based on the quantities and obligations of a disarmament covenant, the existence of other semi-official training arrangements would represent a grave evasion.

OFFICERS' TRAINING CORPS

Many of us who have been members of Officers' Training Corps, or still are, will probably face the implications of this reasoning with the greatest reluctance. The matter has been the subject of acute national controversy in England recently, and will no doubt arise with equal force in other countries. Our loyal recollections of these organisations, and attitude towards them, makes this subject a very difficult one. But the fact remains, and we cannot possibly ignore it, that if a reasoned disarmament scheme comes forward embracing the subject of combatants, then all such organisations in all countries will either have to be contributory towards the agreed totals of officers, brought into the official scheme, or else lose their military identity and characteristics. The same principles apply to the training of N.C.O.s, and the various national organisations which can be regarded as supplying this important combatant type. The great services rendered by British organisations of this kind in the early years of the war leave no doubt as to their potentialities, and of their bearing on a disarmament scheme in which officers were strictly limited.

It is, of course, quite clear that this process cannot be carried to the limit, and it would be absurd to suggest that all forms of

training in leadership and discipline must be eliminated from national life. We are only concerned with training for definite military leadership producing an individual who can take his place in an army without any conversion lag as to his military training in the sense of knowledge and control of weapons, and their organised use.

Although objections will, of course, be raised in many quarters to such arguments by the well-known method of carrying them to an absurd limit and pointing out its impracticability, yet in actual fact there is no difficulty, when faced with an organisation, in deciding whether or no it comes under a category contrary to disarmament principles or a covenant.

INFANTRY

This is mainly a question of training in the use of arms, coupled with the orthodox forms of combined military action with such arms. A Chicago gunman is not a soldier from our point of view, nor are those fine athletes who take part in the great national gymnastic displays of Czechoslovakia. But the idea of a police force in which every man is a thoroughly trained rifle-man, some with machine-gun knowledge, and all with group training—in other words, a formation in which every man is a soldier with the exception of the uniform—is purely Gilbertian, if we are thinking in terms of genuine disarmament. The latter would have to take the view that the real test is training in the use of arms in organised groups of certain size. There must be exceptions, such as men genuinely training for shooting competitions, such as Bisley, but there is no difficulty in distinguishing such activities at present from others which would represent treaty evasion. Of course, this might be made a method of evasion, but it would require expansion to such limits that the idea of concealing the activities would be grotesque. In any case, if it arises under a disarmament regime it must be faced and dealt with. There are various possibilities related to defining the scope and the type of weapons employed by such clubs and organisations.

MILITARY SPECIALISTS

The Great War developed this type of combatant in a very high degree, as seen by the formation of machine-gun and tank corps,

and brigade and battalion units for bombing and other special uses. If, for example, the allocation of tanks to a given nation were five hundred, with, say, five thousand permitted specialists, it would be right against disarmament standards to hold another few thousand enthusiastic amateurs trained for tanks under an organisation which was civilian in name but military in all its effective characteristics. The same point applies to any one of the new types of specialist combatants. It is easy to see that if a regime of rational disarmament is eventually obtained, and if evasion were contemplated, this method would at once suggest itself.

The practical disarmament requirement is simply limitation by categories in all such cases, taking special note of any possible overlapping introduced by the fact that these newer weapons tend to be employed, not only in their own new organisations, but also in a more flexible manner as part of normal infantry formations.

The question of military specialists arises acutely in any case where, in principle, weapon training finds a close counterpart in civilian or peacetime activities. The one supreme example of this is the aviator, which is dealt with below under the section on "Aircraft." It is fully realised that there are a number of military functions in which the civilian parallel is so complete that no technical training and very little military training are required to make the individual available for war. There are the cases of lorry and car drivers, telephonists, cooks, and a host of others. But here again there is no real difficulty in identifying those types which are of acute importance to disarmament, and the great distinction is the one between combatant and purely service uses. It would be absurd to argue that because of the existence of such cases, or, say, some more marginal types, therefore nothing can be done.

ARMAMENT PERSONNEL

The case of the armament or munition worker and specialist admits the same type of treatment. We have a whole range of types from those where the military and civilian function are almost identical, right up to the extreme case where the two functions have entirely diverged and the armament worker is, so to speak, in the spear-head of the national striking force, contributing to the rapid development and production of the weapon

itself. We have dealt elsewhere with the most critical cases, and there is no need, for example, to comment upon those involved in producing weapons. Any disarmament scheme which takes care of armament production on the lines suggested in these chapters will automatically rule out a substantial reserve of armament workers, for there will be no outside production to engage them.

Everyone will appreciate that the operation of disarmament in relation to combatants cuts across a host of interests, threatens many fine traditions and organisations, which in the past have been universally admired. This is unfortunately bound to be the case. But the real question is whether our sole objective is to bolster up a dangerous past or produce a more stable future. If it could be shown positively that some fine old tradition or organisation stood in the way of peaceful progress, and threatened the health or life of millions, and if the issue were very clear to all concerned, the traditions of the past would never be allowed to block the needs of the future. This is indeed the situation with which we are faced, and if we believe that the peace of the world can be stabilised through disarmament, then equally fine traditions and organisations can gradually be built up in support of the new objective, and it is perfectly consistent for those who supported and shared the loyalties of the past to make the same firm contribution towards the security of the future.

AIRCRAFT

Viewing disarmament as a matter requiring technical solution, the problem of the air is one of the most difficult. This is widely recognised, and to such an extent that it has often been claimed as a matter rendering other forms of disarmament useless, but this is an unnecessarily pessimistic conclusion which hardly arises from the cold facts of the case.

The difficulty in question is one of a general class, examples of which have arisen at different times to cloud the whole disarmament issue. There are, of course, in the normal peacetime equipment of an industrial nation a number of items, processes, or materials, some of which exist in great quantity, which are of immediate use at the outbreak of war. Examples at once spring to the mind, such as the use of the taxi-cabs of Paris in the dramatic move which checked the first German rush, or the use of the

London motor-buses and other forms of transport by the British. A whole range of such elements of war potential can be listed, and we have already drawn the sharp distinction in principle between those which need consideration in a disarmament scheme and the remainder which can be ignored. Such factors compel disarmament consideration in so far as they substantially add to the surprise striking-force of a nation, as distinct from their cumulative and contributory effect after long periods, and they approach this condition of surprise value as they acquire the casualty-producing characteristics of a weapon. For instance a motor bus has the same function in peace and war, it simply conveys individuals or materials, it is in no sense a direct casualty-producer, nor can it be so converted by a series of quick industrial processes.

But aircraft depart perilously from this standard of safety, and even in their commercial or peacetime form and design they may to a certain extent be regarded as a weapon. It is perfectly true, as shown elsewhere, that they are not weapons when used alone, and they depend entirely on the employment of standard casualty-producers to acquire this military value. But, regarding a complete weapon as the combination of projector and projectile, there can be no doubt that the commercial aeroplane can become a projector at the outbreak of war. The facts that it operates in a new medium, the air, its great speed and mobility, bringing it within effective reach of enemy formations and peoples, and the simple fact that it can employ gravity as the motive force for the projectile, give it a military striking-value regarding which it is not removed in principle from other forms of projectors, such as heavy guns. We can take it for granted that we shall see enormous development of peacetime aviation, or in any case we must take that as a possibility which must be faced by disarmament, and the question at once arises as to what effective measures, if any, can be proposed.

MILITARY USES

Aircraft serve two main purposes. They can be employed as service machines on such work as intelligence, reconnaissance, photography, and artillery co-operation. Secondly, by the use of machine-guns, explosives, and gas, they become weapons and casualty-producers. Their special characteristic as a weapon, their peculiar value for the disorganisation, demoralisation, and massacre of civilian populations, has been thoroughly ventilated.

It is not my intention to embark upon descriptive forecasts of such uses, but it is necessary to establish the real and terribly important possibilities. To halt before the air problem and to check the momentum of disarmament by attempting to minimise the dangers of the future is useless.

From a cold military point of view, the effect of a weapon is not only governed by the nature of armament itself, but even more by the type of objective, and the greatest effect is obtained from maximum suitability of both. In the case of high explosive and gas there is no better example of such optimum conditions than their use by aircraft over civilian centres and populations.

So far as explosive from the air is concerned, we have a maximum density of structures, lines, and centres of communication, nucleii of organisation, and density of human objective. A few simple arithmetical calculations remove the terrible possibilities of explosives from the air beyond any shadow of doubt, for one only has to take the results achieved by the comparatively feeble efforts during the war, use them as a basis, and work out the possibilities in terms of material destruction, mutilation, and death under conditions of modern and future aircraft density and quantity. The conclusions are appalling.

The point is focused by an illustration provided by Brigadier-General Groves, the well-known authority on air matters. In his paper before the League of Nations Union in December 1928 he said : " The largest bomb yet dropped from an aeroplane weighs four thousand pounds. This bomb was dropped in an experimental test in America, and the following account of the results is illuminating : ' The explosions threw a dense cloud of earth to a height of one thousand feet. The crater averaged sixty-four feet in diameter, with a depth of nineteen feet below the original level, and a rim about five feet high. The volume displaced was one thousand cubic yards.'

" The immensity of this explosion may be pictured when it is remembered that one thousand feet is twice the height of the dome of St. Paul's Cathedral."

Such a bomb dropped in a London street between high buildings might well extend the area of demolition and death to a radius of several hundred yards, disorganising all essential services, light, water, and gas, in much greater zones. Fires would be started, and hundreds of civilians might well be dismembered, crushed, or blown sky-high. Carry the matter a step farther, and imagine the dropping of a few thousand, or only a few hundred,

such bombs over a large city, and it is not an exaggeration to state that the integration of all these varied effects on property and the inhabitants would amount to the destruction of the city. Follow this with a gas attack, and a very high percentage of the whole population might easily be wiped out. This is a cold, but not misleading, view of the possibilities which disarmament would endeavour to prevent.

GAS AND AIRCRAFT

Attempts have been made to minimise the possibilities of gas from the air, but they are, unfortunately, swept aside by the facts. Here again the cold technical consideration is the combination of weapon and objective. Gas—using the term to cover all types of poisonous war chemicals from pure vapours to particulate smokes—requires certain conditions for maximum effect. Whatever the method of discharge, there is a zone in which concentration varies from maximum to minimum, and in its results from rapid death to painful discomfort. The military aim is to achieve coincidence of high density and objective, and in this respect gas was inefficient during the war, but it moved towards efficiency in various ways, notably by the evolution from early cloud discharges to the Livens projector. We were beginning to make the discharge occur in the region of maximum density of human objective, say relieving divisions or crowded billets. Again, war use was relatively inefficient because the objective was unsuitable in the sense that it possessed highly developed and disciplined protection, and the contrast between enormous mortality on unprotected troops and normal mortality in the face of protection was frequent and striking.

The use of gas from the air on crowded cities eliminates the above disadvantages from the military point of view, and introduces the ideal objective. In the first place, we would anticipate big zones of very high concentration. The processes of physical and chemical dissipation which occurred in open spaces during the war under the influence of wind and the absence of gas barriers probably saved the lives of hundreds of thousands of men, but in cities these safeguarding conditions would be at the minimum, or non-existent. The flooding of, say, a few square miles in a city represents the pouring of gas in high concentration into a container in which it would remain unchanged and effective for long periods. We should expect to reach the concentration

which occurred on a few occasions during the war and produced sometimes over fifty per cent. of death.

The further technical consideration is, of course, the unprotected nature of the human objective. It might be possible to equip a whole nation with gas masks, but, even if we admit that, it would be a colossal task to have a fraction of the certainty—which we had on the front under a rigid discipline—that these appliances were in working order. There would be masses of children, invalids, women, and careless individuals, who would be virtually unprotected, and we have to take the view that the use of gas on civilian population from the air is substantially and technically the use on an unprotected objective. This is the true position to-day, and even for the future any other view is hope, but not fact. Under such conditions there is no shadow of doubt that aircraft by this means could produce a density of casualties and death in space and time which has never been equalled nor conceived in military operations or serious military thought.

It would be difficult to overestimate the possibilities, and to present views which were alarmist because unfounded. The concentration of certain gases to produce death, or worse, in the absence of protective appliances and discipline, are extraordinarily small, and therefore easier to achieve. Figures from the Air Ministry based on actual measurements show that the total weight of solid particles in an average London fog in the years 1926-7 was of the order of one pound per million cubic yard, a concentration of about one in a million by weight. Now, lower concentration than this of certain war gases, notably the arsenic smokes, which we have mentioned, produce effective results, casualties in short periods, and death for longer contact. It is not difficult under a regime of unrestricted development to contemplate bomb and container designs which would release poison-gas to dissipate uniformly in a low-lying cloud or death-blanket not higher than our tallest buildings. But assume a blanket one hundred yards high, which gives a big margin of error, and we find that less than a half-ton of chemical is sufficient to produce effective saturation over a square mile. Even if you multiply this by a thousand, to allow largely for wind losses, barriers, and higher concentration, you are still far within the limits of practicable gas attack from the air. We can actually fairly visualise an organic arsenic fog incapacitating a very high percentage of all the inhabitants of a large town, rendering them helpless against

following attack by highly lethal compounds if the former were not sufficiently potent to kill.

When we begin to ring the changes as between explosive, lethal gas, and particulate or fog attack, we find infinite possibilities and combinations of disorganisation, demoralisation, and massacre in which fact could hardly be rivalled by imagination.

It would therefore seem that the air question in disarmament is a particularly important one, and may be complicated by the rapid convertibility of commercial craft. The problem of air disarmament resolves itself into two distinct parts : the limitation of military aircraft, and the conversion and use of commercial planes ; but, although they must be considered separately, yet finally the most important aspect is the relation of one to the other.

MILITARY AIRCRAFT

This term is employed to cover all aircraft in the official land, sea, and air forces of a nation. As we have seen, such craft serve two main purposes—casualty production and a service function. The first question which arises is whether these two categories can be regarded as separate from the point of view of limitation. The fighting planes designed to use machine-guns, explosives, and gas obviously require special consideration on account of their maximum possibilities of civilian attack. They alone, or with commercial craft, according to quantities available, introduce the possibility which might be questioned, but could not possibly be ignored, of imposing a rapid decision by outlawed force in the absence, or with the minimum, of normal land operation, brushing aside the processes of peaceful settlement and the mechanism of disarmament which might otherwise have been effective. There is no doubt that this category requires severe reduction and limitation from the point of view of disarmament, for equilibrium and stability through ratio rather than quantity is probably less effective in this than in any other case of armament.

But can we adopt a less anxious view with regard to the service machines not specially designed for aggression? If military departments wished to impose a basic difference in design, and could show that it was effective as regards conversion, we might view with equanimity a greater freedom regarding this type of machine, but we cannot in this discussion make any such assumption, for we know that, unless and until designs are purposely evolved to meet this point, conversion will be carefully considered

and probably easier than in the case of commercial craft. It therefore seems clear that we must treat all military aircraft as potential or actual casualty-producers, and view them in this way so far as disarmament is concerned.

The obvious requirement is the most drastic limitation in order to limit the possibilities of rapid effective civilian attack to the very minimum. This is the logical viewpoint to be taken as regards permitted quantities within the agreed ratio.

Treatment of the limitation of military aircraft under a disarmament scheme involves the same considerations which we applied to normal armament, and the usual question of production lag arises. We must therefore ask whether under a scheme of agreed reduction its stability could be disturbed suddenly by the quick expansion of production and supply. The special property of aircraft manufacture, which we found was not applicable in any critical way to normal armament, such as heavy guns, is the dual function of peacetime plants, not official establishments, serving the supply of commercial aviation. Regarding aircraft as projectors, it is probably true that they present the one important case in which strict limitation of official sources of production within a disarmament scheme would be in greater danger of being prejudiced by the existence of peacetime plants than for any other item of normal armament, and as the designs of military and commercial aircraft converge the truer does this become. This magnifies the importance of imposing difference in design wherever possible, which is discussed below under "Commercial Aircraft." But ignoring this point for the moment, and assuming that the question of commercial types can be taken care of in some other way, what are the productive characteristics of military aircraft from the point of view of disarmament?

The whole story of the development of such aircraft in the U.S.A. during the war has been very thoroughly exposed in the American records. The facts are significant, because, in spite of the leading part which the U.S.A. played in the early development of aeronautics, yet she had lagged behind other nations, so that when war broke out in August 1914 it is said that she only possessed five officers who could be regarded as the technically trained personnel of the U.S.A. Air Service, and even in 1917, when the other Allies had made enormous strides in air war, she still possessed only about sixty officers and a few serviceable planes for training purposes. At the outbreak of war Germany is said to have had about a thousand aircraft, France and England each

about three hundred, whereas in 1917 the U.S.A. possessed only about two hundred of a relatively obsolete type.

The early U.S.A. activities in 1917 throw light on the broad question of the convertibility or application of other engineering plants for aircraft manufacture. In April 1917, America cabled England, France, and Italy to send aviation experts, and soon dispatched to Europe a large number of skilled mechanics for training. The position is summed up in the following words taken from the official record, *America's Munitions* : "Nor was there in the U.S.A. any industry so closely allied to airplane manufacture that its engineers and designers could turn from one to the other, and take their places at once abreast of the progress in Europe. There was little or no engineering talent in the United States competent to design fully equipped military aircraft which could compete with Europe. Our aircraft producers must first go to France and England and Italy, and ground themselves in the principles of a new science, before they could attempt to produce their own designs, or even before they could be safe in selecting European designs for reproduction in this country."

For such reasons the lag in aircraft production in the U.S.A. in the early stages can hardly be employed in drawing fair conclusions as to time lag under modern conditions, although the generalisation regarding industrial conversion of engineering plants is still valid. But the work went forward under a terrific impetus, and had such astonishing success that the facts surrounding later production are certainly relevant. We can only take a few official cases.

In the first place, the very nature of aircraft suggests long time lag to the technical mind. There would, of course, be variations as between the mass production of a highly standardised very light Moth type and heavy bombers at the other end of the range ; but, when we think of the engine and the large number of other parts and spares required for one machine, we see that under the most favourable conditions the problem is not simpler than mass production of a light car, which involves many months before bulk supplies start, and further months before the full programme is attained. One would class bulk manufacture of heavy bombing machines nearer in production characteristics to a Bentley or Rolls car. The Handley-Page bomber required one hundred thousand separate parts. A large number were ordered in the autumn of 1917, but only seven complete machines had been assembled by the date of the Armistice.

Aircraft engines would alone govern the production periods in expansion from a position of armament limitation. The peak of U.S.A. aircraft achievement was the Liberty Engine, and in this connection we learn from *America's Munitions* : " As an achievement in speed in the development of a successful new engine this performance has never been equalled in the motor history of any country. No successful American automobile motor was ever put in production in anything under a year of trial and experimentation. We may well believe that in the third year of war the European aviation designers were working at top speed to improve the motive power of airplanes ; yet in 1917 the British War Cabinet report contains the following language :

" ' Experience shows that, as a rule, from the date of the conception and design of an aero-engine to the delivery of the first engine in series by the manufacturer more than a year elapses.'

" But America designed and produced experimentally a good engine in six weeks and a great one in three months, and began delivering it in series in five months. This was due to the fact that we could employ the best engineering talent without stint, to the further fact that there were no restrictions upon our use of designs and patents proved successful by actual experience, and to the fact that the original engine design produced under such conditions stood every expert criticism and test that could be put upon it, and emerged from the trial without substantial modifications."

We are not going to revive any controversy about the Liberty Engine, its relative excellence and how much it owed to Allied experience, and only wish to extract from the above enthusiastic account the fact that the best U.S.A. effort imposed a long time lag which is summarised by a statement from the same record :

" The quantity production of Liberties may be said to have started in June 1918, one year after the engine's conception in Washington."

The first service plane programmed for manufacture was the De Haviland, of which a sample was received in July 1917. The first plane was ready to fly in October, but the process of adapting and standardising U.S.A. plant was constantly changing, and the final model only came forward six months later, over four thousand being produced by December 1918. Again, the Hispano Suiza 150 h.p. and the Le Rhone 80 h.p. engines were highly standardised products in European factories, all assistance was

given by foreign manufacturers, yet in the first case thirteen and in the last eight months elapsed to get the first engines from production tools.

Some idea of other features which govern the production of military planes, and the conversion of commercial craft, is provided later. It must be remembered that sighting, bomb-dropping, and tank-armouring all add to the production periods, and help to form the true picture of time lag in relation to disarmament.

It is perfectly clear from all such facts so clearly revealed by the American effort, and, indeed, from a general knowledge of this type of engineering process, that the conversion lag in the production of aircraft is long and very similar to other forms of normal armament. If the manufacture of such craft were limited, so that capacity was framed and could only feed supply in a manner consistent with the agreement, there would be no question of a sudden flooding of the military equipment of a nation with large quantities of unauthorised aircraft able to take part in some decisive surprise.

But, as we have often repeated, the aeroplane is only the projector, and the question of suitable munitions arises. This is mainly a matter of bombs.

AIRCRAFT BOMBS

The American experts began to consider bomb supply for aircraft soon after they entered the war, but it appears to be a fact that by the time the Armistice was signed none of their own bombs were ready for use on the front, although a great quantity of unloaded bombs had been manufactured. It is therefore obvious that there was no easy and quick way to bulk bomb supplies for aircraft, and the reasons are well shown in the detailed history of the factories which engaged on this production.

The efficient use of aircraft bombs involves complicated sighting arrangements, which we discuss below with regard to the convertibility of commercial aircraft, but it also requires a properly designed projectile. Aircraft bombs were shaped to offer minimum resistance, with specially designed fins or tails to eliminate the tumbling tendency, and they had to be adjusted for discharge from a very sensitive release mechanism.

There were three kinds of bombs : for demolition of structures and works, fragmentation bombs for casualty production, and

incendiary bombs, with various sizes and calibres of each to meet different tactical needs. The general principle was a container with an appropriate charge—say high explosive for demolition—which was set off by a detonator separated from the charge in transport and automatically released by the discharge mechanism as the bomb was dropped, allowing the detonator to slide into position in order to explode the bomb as it met its objective.

The first bomb contract was placed in June 1917 for five hundred heavy bombs, for which designs and working drawings were complete when the U.S.A. entered the war. By April 1918 the contract had been increased to nearly thirty thousand, but the production was slow, due to constant changes of design in the firing mechanism, and in June 1918, when nine thousand bombs had been produced, the supplies were entirely cancelled. The history of the demolition bomb provides a similar story of relatively slow results, in spite of great efficiency, with great stimulus and resources behind solid and alert manufacturers. Thus, in December 1917, a contract for nearly one hundred thousand of the small twenty-five-pound bomb was placed, but in June 1918 the contract was halved, owing to unfavourable reports from the front. Even later, when early troubles of design had been largely overcome, the firms concerned took many months to reach bulk output.

The fragmentation bomb appears to have given less difficulty in production. Its characteristics were a very thick wall and smaller explosive charge, with an instantaneous firing mechanism in place of the delayed fuses which were employed with the demolition bomb to allow it to penetrate the target before explosion. Here the lag in production was reduced owing to the fact that the envelope or container could be made by machining a rejected three-inch shell, and the fact that contracts were placed to convert half a million of such shell into fragmentation bombs constitutes an important argument for the strict limitation of normal projectiles, so that they should be used for their own agreed purpose even though there may exist adequate arrangements to limit the projectors or guns themselves. In this case, although the contract was placed in August 1918, and the operation was relatively simple, yet by the end of November only about twenty thousand had been delivered.

The production lag with regard to the timing device is interesting. Six hundred thousand were requisitioned in July 1918, but by the end of November less than half had been supplied.

The incendiary bomb was a real need in normal operations on the front, mainly for the tactical purpose of destroying forest or wood cover. Some readers may remember the constant but futile efforts to burn High Wood when it became a serious obstacle and caused such frightful casualties in the Somme battle. In spite of violent efforts, no really satisfactory type was produced by any country during the war. In the U.S.A., some eighty thousand containers or shell envelopes had been delivered ready for loading by the time of the Armistice ; these were of the intensive type, each weighing about forty pounds, the charge being oil emulsion, thermite, and metallic sodium. It is of interest to the dwellers in cities that the sodium was included, so it is said, to discourage attempts to extinguish the burning charge, the point being that metallic sodium explodes with violence when water is poured on to it.

We thus see that the war left us in a position of relative inefficiency as regards aircraft bombs ; the three types discussed were not entirely satisfactory, and the gas bomb was much less advanced. I well remember important discussions by Allied Committees in 1918 whose conclusions deliberately retarded development in this field, symptomatic of a vague reluctance to advance the cause of gas which appeared on various occasions, and in this case was strong enough to retard development.

It would thus seem that there is some measure of possible safeguard with regard to the actual air projectile. As to development, we only have vague indications on the steps taken since the war.

Various nations have undertaken systematic bomb-dropping tests—witness the U.S.A. example referred to above, and the recent agitation in England about the official use of the Berkshire downs for such purposes. But how far nations have secretly improved bomb design and remedied known defects is not clear.

If disarmament is really coming forward as a practical issue, it is regrettable that a state of relative lack of development should have been changed since the war, for every step towards rapid and efficient use increases the difficulties of the task of disarmament. In any case, if an intelligent view is taken about the development of new armament types, and if this is recognised as a disarmament issue, it would be the worst form of folly to contemplate or permit any further development of aircraft bomb, and in this matter the measures which we have discussed under the new agencies of war are applicable. With regard to production and supplies, the

simplest course is total prohibition and absence of any productive capacity. Taking the whole series of operations relating to the shell envelope and its special design, the timing mechanism, the various fuses and detonators, the charges and the operation of filling, there cannot be much doubt that prohibition or agreed quantity limitation could be rendered effective.

It might be asked, Why not suppress military aircraft entirely? Most of the reasons which have been advanced against such a course of action find little support in reason. The idea, for example, that the use of military aircraft satisfies the most efficient and modern standards of fighting is correct, but provides no adequate reason for maintaining them if our objective is stability through disarming instead of through war. This is part of the whole question of the desirability of new armament types. The recent discussion in the House of Lords exposed a further argument for military aircraft which appears valid at first sight. There is a powerful school which regards aircraft as the most efficient means of performing certain police duties in less civilised parts of the world, illustrated, for example, by the recent disturbances on the north-western frontier of India, and by the operations in the region bordering Arabia and the Persian Gulf. But here again the argument only holds good under a regime of armament, and it would become of minor importance if it were established that military aircraft were a basic obstacle in the way of disarmament, for we should presumably find other ways of policing these regions, as we have done in the past.

The outstanding reason which has been advanced for retaining military aircraft is, of course, related to commercial planes. Nations argue that they have, or at some time might have, inferiority in this respect, and that they need the military craft to neutralise the disparity, the point being that at the outbreak of war all aircraft would acquire military characteristics. This, of course, is the argument of expediency, and it is premature until the world has thoroughly explored the question of conversion of peacetime craft, and really decided that nothing adequate can be done. We must now turn to that problem, and see what possibilities there are of meeting the difficulty on reasoned grounds.

COMMERCIAL AIRCRAFT

At this point we cannot begin by accepting the claim of the inherent rapid convertibility of commercial aircraft for aggressive

purposes without examination. We must obviously agree that where such craft can perform service functions for armies without any conversion there is no check or obstacle beyond the time lag in training the personnel to the point of military utility. But that is not the real trouble, because an excess of planes for observation and similar purposes, although it may be important, is not decisive in the sense of massed aggressive attack on towns and centres of organisation. The real point is mechanical conversion for such aggressive purposes, and it is that which we must examine. Can a commercial plane be fitted to drop explosives and gas in five minutes or a few days or weeks ?

INCIDENTAL DISARMAMENT CHECKS

Let us at once dispose of the simplest part of the problem, for there are certain checks which would operate regardless of the mechanical conversion of the plane or projector. The kind of hostilities which we are visualising and trying to prevent really require, or would be best performed by, the availability of large stocks of specially designed bombs containing explosives and war chemicals. In a rational scheme of disarmament there would be certain difficulties in this direction which we have discussed elsewhere. We should have absolute prohibition of preparation for gas warfare. There would be, if the scheme were effective, no stocks, nor official production, nor special private production of the chief gases, or, rather, no adequate stocks, the exceptions at present being large amounts of liquid chlorine and smaller amounts of phosgene. There would be no production, design, or stock of special containers, such as suitable bombs, and these measures would be covered by general restrictions, cutting across all these activities by way of legislation and other conditions imposed on personnel.

Although nothing appears as yet to have been proposed regarding the use of explosives from the air, it would seem a logical disarmament measure to forbid all such use, and this would affect all aspects of relevant armament development, except possibly the supply of the explosive itself, some of which would be permitted for the purposes of normal armament within the limits of the scheme, and is needed for peace uses.

The prohibition of the combined use of explosives and aircraft is worthy of consideration for several reasons which do not apply

to artillery, unless and until heavy guns of the Big Bertha type become a serious threat to civilian populations. The latter is not an immediate danger, and it can easily be checked through normal disarmament. The special characteristic of attack by aircraft bombs, and the vulnerability of civilian objectives, provides the first reason ; while the second is the removal of the hampering argument that no one can say where the military objective ceases and the civilian begins. Rather than use this as an excuse to destroy women and children in towns, it would surely be wiser to cut the Gordian knot by prohibiting the use of explosives from the air.

In a system of rational disarmament, properly operated, it would seem that the only projectiles available for outlawed hostilities in the air would have to be of some rapidly improvised and designed types. Could this be done ? All the facts and considerations of armament production show that it could not be done immediately, and there would be a time lag to reach quantities ; for it must be remembered that, to produce the decisive effect which disarmament is designed to prevent, considerable quantities would be required, even by use from the air. It would not be enough to make one or two casual attacks, even though they might have very terrible results locally. A nation with any moral stamina would not be beaten down and prevented from reply by a few acts of piracy ; there would have to be a systematic and sustained attack, which would meet with great losses in the process. On the other hand, we must admit that the quantities involved for a possible success would in the nature of things be less than those necessary for a sustained land attack, this being due to the specific nature of the material objective, and the intention to bring a decision rather by moral effect than by the usual military processes. Under a rational system of disarmament the idea of an absolutely sudden and adequate attack is a fallacy ; there would be a definite time lag, which would add to the risk and reduce the incentive, although these would be less and more, respectively, than in the case of normal hostilities. We can arrive at one very sound conclusion, which is that, although the menace is real in the absence of disarmament, it is reduced far more than most people think in the presence of a comprehensive scheme on the lines and principles outlined in these chapters.

We now come to the question of any possible checks applicable to commercial aircraft or their personnel. Our objective is

maximum freedom in developing such craft, with the minimum possibility of its use as a weapon in war.

DESIGN AND TECHNICAL CONVERTIBILITY

It is perfectly clear that peacetime craft can be designed either for maximum or minimum speed of conversion. The first practical measure is obvious. It is utterly inconsistent with disarmament intentions that peacetime machines should be specially designed for possible aggressive war use. It appears that Italy has openly recognised the convertibility of commercial aircraft by two decrees published in 1927. The first, according to General Groves, in his above-mentioned paper, empowered the Italian Air Minister "to requisition all aircraft in case of urgent necessity for mobilisation and compel all constructors and owners of aircraft to observe certain requirements which will facilitate the transformation of civil into military aircraft in the space of a few hours." The second contained articles which made compulsory "the construction and equipment of civil aircraft on lines which rendered them more readily adaptable to military use, and all aircraft were directed to be registered under specified categories as auxiliary military aircraft."

We are not discriminating in any way against Italy, and possibly other nations have taken the same steps without openly saying so. But it seems doubtful whether they can realise what a homicidal policy they are pursuing. Presumably convertibility does not only refer to aerial photography, and it can hardly ignore suitable mechanism or fixtures for dropping bombs. It will probably be said that they had nothing else in view but strictly military objectives, but the experience of the last war, and the practical impossibility of drawing a sharp line, simply means that this is the first step in the wholesale slaughter of civilians by aircraft fleets, and by personnel to whom, to-day, the idea is so repugnant that they would read these lines of mine with the utmost indignation.

In any case, such steps towards convertibility at least imply that steps are necessary, and that there would be a time lag if the steps were not taken. The first obvious disarmament measure is therefore an agreement that no peacetime aircraft shall be designed or fitted specially for such purposes. This idea has already appeared in official discussions. Thus we find in the League of Nations report of April 1927, following the meeting of the Preparatory Commission for the Disarmament Conference of December

1926, Article A.E., paragraph 2: "The High Contracting Parties shall refrain from prescribing the embodiment of military features in the build of civil aviation material so that this material may be constructed for purely civil purposes, more particularly with a view to providing the greatest possible measure of security and the most economical return." It is only fair to state, although somewhat disquieting, that we also find the words " the delegation of Italy makes a reservation with regard to Article A.E."

This leads us a step farther, for if aircraft can be designed with maximum suitability for war use, it is equally certain that technical methods can be found which would place the maximum obstacle in the way of such use. It is extremely doubtful whether a competent group of aircraft experts has ever considered this problem in an unbiased technical atmosphere, and some will regard it as a ludicrous suggestion, but from the point of view of disarmament it is an essential and logical step.

SIGHTING, BOMB-DROPPING, AND OTHER APPLIANCES

The extreme difficulty which we had in the war to adapt aircraft for efficient machine-gun use leaves no possible doubt that peacetime craft could be designed to make such extensive conversion involve a very considerable effort and time obstacle. It would not be difficult to design aircraft so that substantial reconstruction and periods in works would be necessary to adapt the two principles of universal mounting and firing and of synchronised machine-gun discharge through propeller spaces.

Then, again, with regard to the other method of aggression—the dropping of casualty-producers or agents of destruction, such as bombs—we imagine it would not be a technical impossibility nor a serious difficulty to impose features upon commercial aircraft which rendered it exceedingly difficult to operate anything but the most primitive bombing without serious adjustment in works. From the point of view of sighting and aim related to any specific relatively small objective, it is incontestible that something could be done ; the difficulties in evolving suitable arrangements for legitimate military aircraft leave this beyond doubt. It is true, however, that with very large objectives such as great towns, with the simple purpose of the maximum destruction and civilian casualties, these refinements are not so necessary ; it is more a question of ensuring rapid discharge of maximum tonnage. But

here again it is a question of a very specific adaptation and mechanism ; the ballistics, control, and flight of the machine have to be considered, and it is not enough to visualise mechanics dropping improvised containers out of the cabin windows of peacetime craft.

We are not entirely devoid of facts on which to base an opinion in the absence of expert investigations, for we have the knowledge of the steps which were necessary during the war to render aircraft even reasonably efficient in the use of casualty-producers, such as bombs.

It must be remembered that the dropping of bombs upon a dense civilian objective is not the simple operation of halting directly above it and dropping a metallic container full of some form of chemical. We have to visualise such aircraft avoiding active and organised counter-measures, and moving at maximum speed. The path of the bomb thus becomes a curve, in which it first moves under momentum from the velocity of the plane and gradually assumes a vertical downward course, reaching a straight line if the plane was flying at a sufficient height. Simply stated, the problem is the launching of a scientific device—a bomb—upon a distant objective, which can only be attained with any accuracy by taking into account the speed of the craft, its height above the ground, the shape of the bomb, and the effect of wind and air currents. Complicated sights had to be developed and manufactured to adjust for all these factors and allow an accurate hit.

The U.S.A. adapted a British type—the High Altitude Wimperis. Production was decided in 1917, but it was not until November 1918 that some eight thousand sights had been produced. There was no question—far from it—of " overnight conversion " of some industrial plant to produce large quantities of bombing sights, and a glance at this intricate and exact piece of scientific apparatus provides adequate explanation. We may put it as a question, but the answer is not in doubt, whether commercial aircraft could be adapted for effective bomb dropping without being equipped with suitable sights, and whether, under a regime of disarmament which limited production and stocks, the expansion could occur even in a few weeks.

The problem of bomb-suspension and release mechanism is equally important for efficient air warfare or rational disarmament. Some method must be adopted for dropping a bomb weighing, for example, half a ton, and the problem of doing so accurately and efficiently without interfering with flight involves a complex

mechanism which could not be applied to any plane, regardless of its design, but only to those initially constructed to take such an addition to their structure. The release mechanism must add as little as possible to the total weight, and be able to discharge salvos, or series of bombs, with minimum disturbance of plane balance. It is carried, with its attached bombs, under the wings or fuselage or in a compartment of the latter, being controlled by an operator in the fuselage, say in the observer's cockpit. We learn from *America's Munitions*: "The production of the release mechanism, of which several types were made, was one of the troublesome jobs in connection with airplane bombing."

I have referred to sights and bomb control, but there are other very important features of a fighting plane which would all be subject to the same considerations, even if not of such acute importance for disarmament. There is the problem of armouring or protecting the fuel tanks and other vital parts of aircraft, which absorbed many months of investigation during the war, which led to many ingenious suggestions but was never thoroughly solved, although it has been pursued intensively by various Governments since the war. Other points arise such as machine-gun mounting and synchronised firing, protection of pilots and fighting operators, oxygen arrangements, and the whole range of wireless and signal arrangements. We have touched on some of these, but cannot stay to comment on the remainder.

Even if the more essential appliances existed in quantity, it is almost certain that the most efficient commercial plane designed without any view of use in war would not be suitable for rapid conversion. Again, these devices are subject to a specific and substantial lag in production. In addition, there is little doubt that peacetime craft could be designed to increase the difficulty and the time period of conversion for aggressive use, and this point, in a thorough exploration of technical measures for disarmament, should be given as much competent consideration as the converse problem of adaptation for war use.

It is not difficult to imagine some mechanical device, deep-rooted in the structure of aircraft, difficult to remove without disorganising the structure, and without which the movement of the plane would be hampered. It might be intimately associated with the engine or the electrical system, and so placed as to render the gravity feed and discharge of bombs a virtual impossibility. To enlarge in this direction is simply to invite destructive criticism,

and all we need say is that disarmament requires some mechanical check on military convertibility, which is just as necessary and logical as the converse requirement of designing peacetime craft to be suitable for war uses. The same kind of mind which has solved, and is solving, the latter problem will be able to cope with the former. All the usual objections of interference with maximum technical efficiency in the development of aviation go by the board, for they apply equally to modificâtions of peace-design for war, and whether the suggestion is ridiculous and Utopian or vital and practical depends entirely upon the importance which is attached to disarmament, and, on narrower grounds, whether we wish war to retain some of its former less repugnant characteristics or to become a chaotic slaughter-house for women and children.

PERSONNEL AND INSPECTION

If we are looking for maximum safeguards we cannot ignore the question of personnel. We may at least assume that under disarmament the number of military aviators within the permitted establishments will be limited, which naturally reduces their possibilities in the form of attack which we are considering. The problem resolves itself into some control of the much greater commercial aircraft personnel. Let us assume that by agreement we have the absolute prohibition of the use of explosives and gas from the air, or an agreed limitation to strictly military objectives. We know the difficulties of definition, but let us make this assumption for the moment. What measures could we impose upon such personnel in peace to assist the prohibition? There is one obvious measure which emerges from our recent consideration of the question of combatants. When considering that subject, it became clear that disarmament must take note of all activities outside the scheme which substantially threatened its stability. In connection with this principle, we found a class of specialist soldiers which acquired striking value in a military sense without the long periods of training and assimilation into military organisations. In such cases it was seen that limitation was applicable to what we may call their weapon training. Now this applies particularly to the training of civil aviation personnel in the military use of aircraft, and under disarmament there should certainly be total prohibition of such training. Such a

measure might easily involve many weeks of time lag before an adequate number of expert bombers could be produced.

It will be appreciated that the unique position of aircraft in the range of armament as regards dual functions or convertibility for war will also apply to aircraft personnel. For instance, if any normal peacetime occupation involved the use of tanks, then their operators would present a special disarmament problem. So long as peacetime aviation personnel are not trained in the use of weapons or the military use of their craft, they only approach, but do not by any means reach, the position of instability in a disarmament scheme. But whereas in the case of, say, heavy guns or tanks the scheme need not envisage direct precautions in the above directions, they must be considered in relation to aircraft We believe that to-day in certain countries, either through deliberate organisation or quite incidentally, there is a constant stream, almost a rotation, of pilots from military establishments to civil aviation. It is a sort of conscription, with voluntary characteristics, with relatively short periods between the calling up of small numbers of progressive classes. Such a system builds up a huge reserve of essentially competent personnel which defeats any recognised and adequate disarmament principle in relation to reserves. We cannot see rational disarmament evolving without taking note of this situation, and positively organising against it.

In view of the special incidence of this type of warfare upon harmless civilians, women, and children, and of the ghastly results, it has been suggested that aircraft combatants employed in this way for outlawed aggression should be subject to special penalties. It has indeed been a feature, in the past, of international practice and consent that certain types of war activities should impose unusual but generally accepted penalties on the individuals concerned. There is the case of spying in time of war, and there are other possibilities of hostile action, too repugnant to mention, which have never yet been employed, but regarding which it is easy to conceive under the old regime the most severe individual penalties would have been imposed. It might even be possible to carry such penalties under international law into periods of peace which followed any such war, and thus render them more effective.

To my mind, any solution which singles out special individuals, performing detailed duties, for repressive penalties is to be deplored. It places the individual, who has no control of the situation, in the impossible position of choosing between international

loyalty and national policy in an emergency when no choice exists. It could be said that by international law and agreement the individual could be brought out of the ranks of national penalties, but this is an unfair solution, for, however it might operate in peace before and after an outlawed war, it does not cope with the position during hostilities, when the incidence of international arrangements would be diverted and powerless to assist the individual concerned.

The real point of attack is the problem of rapid convertibility, and the question of individual penalties, if any, is a general one, relating to all aspects of breaches of disarmament obligations. There is, however, a suggestion which could be made regarding personnel and inspection. Disarmament requires minimum convertibility, and if the nations reach an agreement on this matter it would be a farcical situation that tourists and commercial traffic should foster aircraft lines and organisations whose machines by their design deliberately defied the terms of the agreement. This suggests a system of inspection at big aviation centres, and some check by means of licence and inspection of private machines, emerging from works and in use.

After all, it is only the technical nature of the problem which fogs the issue and prevents general appreciation of the dangers involved. Suppose nations went a step farther than organising convertible craft and loaded their commercial planes with dischargeable supplies of some disease germ, in order to be able to drop them at short notice, diverting their course and concentrating on some prearranged objective under wireless instruction in the event of, or to facilitate, sudden piratical aggression. One imagines that the public would revolt against such practice, and no decent individual or firm would contemplate for a moment the personal or commercial use of the craft in question—certainly those of other nations. But, compared with this, the preparation of commercial craft for bomb dropping is in no way different in principle nor in possible results. It simply has a less direct reaction upon the mind and conscience of the average individual, because the significance of a few mechanical appliances or adjustments is not so startling as a load of plague germs. If the peoples of the world do not wish to be at the mercy of that uncontrolled and chaotic process of arms evolution to which I have so often referred, nor to have their fate and history governed by it, they should at least see that their official representatives are instructed and competent to tackle its symptoms when they

emerge openly, from the secret enclosures of armament research, and begin to encroach on the common activities of a world at peace.

It is suggested that all these facts and considerations at least show that the air problem is not necessarily and fatally an unsealable and vital breach in the organisation of peace through disarmament. It is indeed a sufficiently grave one to require special and drastic treatment, but there are various ways to check the peculiar danger which air warfare affords of side-tracking the normal, and perhaps the controlled, processes of war by gambling on the results of accumulated terror and destruction in a new civilian battle-zone. Reasoned consideration has brought forward a range of possible measures, the prohibition of these forms of attack, the control of the development and productive facilities which feed them, the inclusion of air personnel, military and civilian, within a rational scheme of combatant limitation, the inspection of private and commercial machines, and the very important mechanical checks to increase the time period of conversion, which includes the prohibition of any arrangements to assist this process. Can there be any doubt that competent and official examination of all such possibilities and others would bring the air problem within the same order of security and stability as other disarmament issues for which a practical solution is already regarded as feasible?

CHAPTER XII

ANALYSIS OF PAST SCHEMES

Essential Disarmament Principles : The Interparliamentary Union—Budgetary Limitation : The Esher Scheme—Combatant Limitation : The Moscow Conference, 1922 : Some Other Efforts : The Washington Conference, 1921–22 : The League Meeting, Brussels, 1920 : The Preparatory Commission, 1926 : Conclusion.

The numerous facts exposed in the previous chapters surrounding the nature and growth of armament have justified certain broad conclusions on which it is claimed the structure of a reasoned and effective disarmament scheme could be based. It was necessary to explore these facts, and if there is anything useful in my particular method of approach to disarmament it will be advisable to probe with more system and depth than is possible in a work of this sort. The points which I have brought forward as throwing light on the characteristics of armament in relation to disarmament are, however, chosen from a much wider field surveyed over long periods, with the standard in view of being representative, rather than the biased objective of supporting any particular argument or case.

Before closing this discussion it would be well to focus these conclusions and broad disarmament considerations or principles by a short summary, followed by a very brief examination of official disarmament proposals which have been put forward recently both before and since the Great War. We cannot attempt any detailed analysis of these proposals, and our object is to see how far they embody the principles which have emerged from our study of armament.

ESSENTIAL DISARMAMENT PRINCIPLES

We start off with the assumption, which is to-day a definite element of international policy and agreement, that we no longer desire to settle national disputes by war. The world has begun to give effect to this idea by creating organisations, such as the League of Nations and the International Court of Justice at The

Hague, in and by which we are developing methods and procedure for peaceful settlement. These processes are likely to be slow in operation, although everything will be done, presumably, to increase their efficiency and their speed of incidence upon national disputes.

Further, these judicial methods are not supported by any substantial elements of organised force, and they rely more on the good faith of nations, with a background of pressure from world opinion. The essence of the problem is to ensure that such methods should have a real opportunity to operate. They could always have been put into operation in the past, but the means of making war were so highly organised both as to quantity and speed of release that there was never any real opportunity for quiet consideration and judicial settlement when national antagonism was reaching the peak. We as nations, knowing our own weaknesses, have therefore evolved the idea of so crippling our striking power that we could not, if we wished, violate our own promises of peaceful settlement. In other words, we have reached the idea of disarmament.

Early, and in fact recent, serious proposals did not go far beyond the conception of reducing the actual combatants and their fighting equipment. It has been assumed, not necessarily correctly, that a crude process of bulk reduction of these obvious and more visible means of hostilities would produce the desired result. Possibly there has not been a very clear idea of the main objective—automatically to ensure sufficient periods of time free from hostilities and at the disposal of the agreed processes of peaceful settlement. But a more systematic and scientific view of disarmament has been emerging—witness the French official insistence upon the importance of war potential—and it seems to me that this very important aspect has not received sufficient recognition and acceptance because it has been carried to impracticable limits. We in the previous chapters have attempted to examine the feasibility and practicability of disarmament from this point of view, trying to evolve its structure from an examination of the relevant technical facts rather than on the basis of some tacit and unexplored assumption that in some curious way reduction in quantity would by itself be effective.

The first broad disarmament requirement which emerged was that the position of armament, using the term in its widest sense, should be rearranged so that the reduced distribution at any given time would make it practically physically impossible for a

nation to break out into outlawed hostilities with any chance of success by the use of those reduced forces. But this only gives us a momentary or short-period safeguard unless another requirement is taken into account. The national power or capacity to feed and rapidly to extend the agreed quantities must itself be so organised that such expansion for effective non-permitted hostilities involves a very long time-factor, or, as we have termed it, a "long conversion lag." These two requirements would bring nations to the so-called safety-level for disarmament.

We have considered at length the various armament types and processes in their bearing on this matter. It has been constantly borne in mind that disarmament must aim at disturbing national life to the minimum. The conclusion has emerged that, taking combatants as the first index of reduced quantity, disarmament must not only deal with their actual fighting equipment, but with any factors which could rapidly expand both, the chief being, as regards combatants, the semi-military organisations, and, as regards armament, the producing capacity of casualty-producers and their essential military accessories and stock. At this point we reach the disturbing influence of the private armament industry, and arrive at the fatal conclusion that it cannot be allowed to remain outside the disarmament scheme, and, if it continues, must be brought into it.

For the whole to be valid and water-tight, it is clear that there must be no external factors which could upset the quantity equilibrium, and this brings us to the broad question of armament type and its evolution. It is inconsistent with efficient disarmament that there should be any important types or a large number of minor types outside the scheme of limitation. The safest position is agreement on the types to be retained, and the application of limitation thereto, with suppression of all other existing types.

These principles, and the measures which emerge from them, represent the static conception of armament, a cross-section of it at any given time, which introduces the broad question of armament processes or activities outside the scheme, which, through development and the influence of time, would neutralise its value. The international equivalence of armament type comes forward as a basic consideration of rational disarmament, with which secret development is utterly inconsistent. The alternatives of open parallel development, a sharing of results, and total suppression have been considered, and there is no doubt in theory, whatever the difficulties in practice, that the latter is the

correct solution. Here we analysed the process of armament growth, and arrived at various detailed measures designed to check each step.

The above framework of rational disarmament involves many other structural elements, some of which we have considered, and leads naturally to the formulation of various practical measures, the nature of which we have indicated in some cases. This, shortly and very broadly, is the position which we have reached. It is now of the greatest interest to see how previous official proposals and discussions conform to, or depart from, the above ideas, and the facts on which they were based. The references to the details of previous proposals are not always taken from the official texts. I have sometimes relied on summaries of the latter, taken, for example, from Professor Baker's admirable book on disarmament.

THE INTER-PARLIAMENTARY UNION —BUDGETARY LIMITATION

Various proposals emerged before the Great War, and we will take as our starting-point the one put forward by the Inter-Parliamentary Union. Its object was a common one in such schemes—the use of a single factor for the incidence and operation of control. In this case there was to be mutual reduction of finance devoted to armament ; in other words, agreement to limit the military budget of each State concerned. Within the budget the direction of expenditure was a matter for each nation, and the concern of no other, nor of the group. The main value of the proposal lies in the reduction of national armament expenditure, and of the indirect influence which this would have upon peace through such factors as diminution of war mentality. But as a true disarmament measure it becomes subject to serious criticism unless the reduced expenditure falls below very low limits.

We have the obvious difficulty of isolating military expenditure in the national balance sheet. There would have to be some standard agreed method which would mean substantial changes, even then evasion would not be difficult. With no limitation on armament itself, it would be extraordinarily difficult to check up expenditure by trying to track the activities which it was feeding. But the real criticisms arise if we assume a condition of absolutely genuine budget limitation. The mere fact that official finances are

controlled, and not men and materials, introduces one great and obvious possibility of disparity inasmuch as there is nothing to prevent additional forces and equipment being raised by financial and other means genuinely outside Government control. It is not difficult to visualise circumstances under which private interests would find it worth while to build up national armament resources, trained combatants, and personnel without any direct financial contribution from the State. There are many other ways to assist industrial enterprises, which under the scheme, be it noted, would suffer no restrictions whatsoever as regards armament, except limited official financial support. Recent history, and past, teems with cases of substantial military organisations on a voluntary basis.

To pursue this matter, let us make the further assumption that coupled with a scheme of budgetary limitation there was an arrangement or covenant forbidding the development of military resources except those directly fostered by the agreed expenditure. This would be necessary in any case, and, although it is difficult to see how it could be enforced without detailed measures, we will again assume its effective enforcement, and see what further criticisms apply.

This brings us to the application of the principles of technical disarmament. Within a scheme of budgetary limitation, assuming its efficient application, could there be such disparity as to defeat the main objective of disarmament, the critical automatic breathing-space for the processes of peaceful settlement? The answer depends upon the extent of the financial limitation. As the permitted expenditure approaches a really small figure, so we can begin to ignore the theoretical inconsistencies of the scheme and the national variations in the employment of armament finance, but for substantial amounts it becomes a very false form of security. This can most quickly be seen, without long discussion, by taking the two extreme cases, first of a nation possessing, say, considerable "police" responsibilities, compelled to employ every penny in keeping an active force to the highest pitch of efficiency with standard weapons, and, second, a case in which no such immediate responsibilities existed, and expenditure was concentrated upon schemes which brought great volumes of armament and combatant facilities to a point from which unauthorised expenditure could rapidly create excessive and powerful forces.

The first nation, faced with all its long-time processes of bulk

armament conversion, would be in the required and anticipated disarmament position, while the second would represent a false stability or equilibrium, able by the touch of unauthorised finance to begin to threaten the peace of the world. The first would have a small fixed, active producing capacity for its guns, machine-guns, rifles, etc., with no quick means of expansion, while the second would concentrate all its expenditure on assisting peacetime factories and the private armament industry, say by subsidy, to get into the position of the maximum possibility of rapid expansion with the minimum expenditure for peacetime supplies. Instead of relatively small factories consuming expenditure on actual armament, such a country would have a widespread system of idle plants or units, so arranged and so supported by intense organisation and preparation, at every point short of supplies, as to reduce to the minimum the conversion period for large-scale hostilities.

Of course, the whole substance of our argument in the previous chapters has been the efficiency of the time obstacle in a disarmed country, but this presupposed a disarmament scheme which took advantage of such obstacles and imposed disarmament measures at specific points with this positively in view. The system of budgetary limitation, however, admits a very different state of affairs, with complete freedom in all steps of armament preparation, except the final one of bulk supplies limited by finance. In our example there would be absolute freedom, and an intensive effort would be made to eliminate all these time-factors; they would operate in the first country but not in the second, where the risk would be measured by the availability of bulk supplies only, which risk could be reduced by all kinds of factors not present in a state of rational disarmament, such as the private industry, widespread armament units, both permitted within the budgetary scheme, and intensive secret efforts to increase producing capacity as the time approached for the hostilities which the scheme was designed to prevent.

Again, a great effort would be made to take maximum advantage of new types which were least subject to the time obstacles of production, which brings us to another criticism and the whole question of type under such a scheme. The latter would permit all forms of armament evolution. It would be an extraordinary coincidence if armament were to evolve on parallel lines, and if some Great Power did not, under a state of such complete freedom, bring forward a decisive weapon—or fondly imagine it had done

so, which comes to the same thing as regards the decision of a staff and Government to make war.

It is not wise that the peace of the world should rest on coincidence or hazard, on an assumption that nations would automatically direct their permitted expenditure towards the same objectives. Military policy varies, secret national research moves in different directions, and we cannot so much assume a converging objective as we could in the case of great industrial concerns, where it rarely arises unless the rival hands are exposed through the marketing of a new commodity, which step in armament can only be safely assumed to occur too late, when war has broken out.

These are some of the basic disadvantages of the budgetary scheme ; and the more obvious ones, such as the difficulty of standardising and defining military expenditure, a uniform type of budget amongst nations, and the varying purchasing power of money from place to place and with time, some of which could be overcome by goodwill, readily suggest themselves, and have been fully discussed in other places. Budgetary limitation is of use as a starting-point in disarmament, preferably associated with other measures to neutralise its gross deficiencies, but as a solution, by itself, it is a snare.

THE ESHER SCHEME—COMBATANT LIMITATION

This was put forward by Lord Esher to the Temporary Mixed Commission of the League in 1922, and is again an attempt to simplify disarmament by limiting one factor, which in this case was not expenditure, but land forces or numbers of combatants. Again, the conscious or tacit assumption was made that this was a factor which could adequately govern all the others so far as disarmament was concerned.

Very briefly, it was proposed to limit the size of the peacetime standing armies in accordance with a ratio amongst the nations which would apply to home forces, deliberately excluding those required for Colonial and Overseas defence, and the reserve or territorial forces.

This scheme is subject to all the criticisms which we applied to budgetary limitation, with one partial exception. It prevents disparity amongst combatants in the standing armies, but it does not, in my opinion, pay adequate attention to the combatant question as a whole, mainly on account of its avoidance of the problem of reserves. This was, of course, most carefully considered

in Lord Esher's scheme, and it is perhaps an injustice to deal with it so shortly as we must.

He visualised a so-called "Period A," during which, after the outbreak of war, the reserves would not be available in any quantity. Even if trained, they could not, for a variety of reasons, be assimilated into the effective military organisation of a fighting army until the end of this period. He apparently based his views on a consensus of military opinion founded largely on the efforts of the belligerents to get their trained reserves into the field at the beginning of the Great War. At some point between two and six months, say four, it could be said that they began to contribute in substantial quantities. Such a period, he thought, would be sufficient to assist peaceful settlement, to cripple the successful outbreak of outlawed war, assuming adequate initial reduction. The latter would govern the size of the forces which could be flung into hostilities at the start, however big the reserves might be, because it appears to be accepted that the most efficient military organisation could not immediately assimilate its reserves by a greater factor than about three times the strength of the standing army. Thus a standing army of, say, a hundred thousand, backed by keen organisation and sufficient reserves, might mean at the most at the outbreak of war an available three hundred thousand, and four months would elapse before further substantial increases could occur.

Surveying the matter impartially, with an eye to safeguards, it is very doubtful how far this military arithmetic could be relied upon in such a scheme without the assistance of technical disarmament. In the first place, it is very doubtful indeed whether any of the Powers engaged in the Great War had consciously and intensively organised to throw in their maximum reserves in the minimum time. It is not clear that they anticipated a long struggle. Germany was relying on a vast initial preponderance of strength.

Then, again, we must take note of type of combatant as regards reserves. In spite of old theories, the face of war is changing, and can we assume that figures which applied, say, to masses of infantry in Germany in 1914 would be applicable to the rapid availability of highly trained reserves for machine-gun, tank, and chemical units? It is true that they require supply and administrative organisation behind them when operating as an organised force, but I would suggest that, if brought to a high pitch of weapon efficiency in times of peace, they can, on account of the nature

of their weapons, be of extraordinary, if not maximum, value for war, without such long periods of personal intensive military training as applies essentially to infantry and cavalry. An excess of ten thousand machine-guns and a few hundred tanks employed by brave men thoroughly conversant with their weapons might well decide the issue in a great battle, although those men, if required as infantry, might be almost useless, and need several months of training. In other words, the increasing number of specialist soldiers in modern fighting armies tends to confuse the case as regards the rapid availability of combatants, and, being a growing tendency, it is of importance with regard to such schemes as the one under discussion. The combatant aspect of the Esher scheme has been thoroughly discussed in other places.

But, however valid it might be, or however transformed, it falls down entirely by total neglect of armament. In discussing the Esher scheme, the League of Nations, through its Temporary Mixed Commission and military advisers, wisely emphasised this point. Those who have read the previous chapters will see that it ignores entirely the basic principles of disarmament as regards armament quantity, type, and evolution, and thereby admits the very maximum disparity amongst national forces, relying only on one factor, combatants, which is unable adequately to control the others of importance for war or its prevention. The Temporary Mixed Commission suggested the subsidiary control of armament directly or through finance, but, in spite of very lengthy discussions, it does not appear that any constructive proposal emerged beyond a decision to study the matter further.

THE MOSCOW CONFERENCE, 1922

This was between Russia and her neighbouring countries. It was again unsuccessful, but its chief proposals are of interest. Land forces were to be limited as to peacetime strength in accordance with an agreed ratio, the reduction to occur in stages. The question of armament was dealt with by agreement as to expenditure upon equipment for the forces permitted, there being a fixed rate for each man under arms. There were to be neutral zones along frontiers, but again the main problem of armament was left untouched because its manufacture and distribution was to be left uncontrolled. The Conference broke up for various reasons, some of a political nature, but the main obstacle was the one which I have emphasised repeatedly in this book—that technical

disarmament must be viewed as a technical matter and not as a search for an unscientific quack remedy over-riding the facts of the case. Thus, certain members of this Conference resolved before it ended to form a committee " to inquire into the establishment of a basis for the solution of the question of technical disarmament."

SOME OTHER EFFORTS

Other unsuccessful but substantial attempts have been made, such as the Pan-American Conference of 1923, and the League of Nations Naval Conference in Rome, 1924. We have already dealt with the Treaty of Versailles in a short analysis, comparing its essential features with the disarmament standards which we have evolved. Its main weaknesses are, of course, that it dealt only with one nation, and ignored very largely the basic problem of type.

Curiously enough, the Treaty between the five Central American Republics brought about by the Central American Disarmament Convention of 1923 deals with the question of armament type in the sense that it limits military aircraft and entirely forbids the use in any way of poison-gas ; but the great problems of type evolution and peace preparation are ignored. This may have been less important from the point of view of expediency in view of the state of technical and industrial development in these countries.

THE WASHINGTON CONFERENCE, 1921–1922

This was called by President Harding to deal with an agenda of three items : the Limitation of Naval Armament, the Control of the New Agencies of War, and the Limitation of Land Armament. It was perhaps the most important disarmament conference which the world has ever held, if measured by its possibilities, its achievements in naval disarmament, the nature and authority of the Powers represented, and its lengthy discussions by the most important, although not necessarily the best informed, delegations from the Great Powers. I have before me a printed account of the statements of the chief delegates, excluding many of the subcommittees, published by the American Government with a breadth of vision which might well be emulated by others, and it runs into nearly two thousand pages of close print.

Yet a search for the beginnings of a rational disarmament structure or a technical objective based on the facts of armament leaves one with a sense of great disappointment. It was in the two last items—the new agencies and land armament—that one expected to see something valuable emerge, but on the latter there is really nothing to say, for political difficulties in the European situation stifled the matter at the outset. The position was focused by Mr. Hughes, of the U.S.A., Chairman of the Committee on Programme and Procedure with respect to Limitation of Armament, and the official account reads : " It had seemed from the outset that any definite programme regarding limitation of land armament was impracticable, for so many special situations would be encountered that the Committee would find its time wasted ; but a point might soon be reached when an announcement might be made, to show the public that the Conference had taken due note of this important matter. The Chairman therefore suggested that any announcement on this point be reserved for the time being, as such a statement at most would be a general observation, and no commitments would be entered into."

This meant stalemate on land armament, and M. Briand's noble speech left no doubt that the political causes were real, and compelled France to adopt a most cautious attitude towards drastic and rapid limitation. But the logical course was not to abandon the authoritative pursuit of the problem, rather to intensify it, for two main reasons. First, it was by no means proved that thorough land disarmament would not contribute to security. To take an example, the point he raised about German armament resources through controlled elements of the private industry in other countries really demanded early and thorough consideration of the whole question of private manufacture. The uncertainty of reduction of German combatants, or of those of any other country, on account of semi-military organisations, should have compelled the most scientific attention to the whole problem of combatant reductions and the maximum support of any measures by parallel national legislation.

In other words, M. Briand's whole speech and the attitude of his great country, justified and understood, should not have been taken as an argument for inactivity or stalemate, nor can I see that he made it so. It should have been the beginning of a most intensive investigation of rational disarmament. The fallacy is, I think, focused in M. Briand's own words. He said that nothing could have given him and his colleagues greater gratification than

to stand before the Conference and say : " We come prepared to make the greatest sacrifices ; our country is safe ; we lay down our arms, and in so doing we rejoice in helping to lay the foundations of a permanent peace." This viewpoint ignores the functions which the laying down of arms on a truly scientific disarmament basis might play in ensuring the safety to which he referred. Unfortunately, the matter had not been investigated sufficiently far at that time, nor may it yet have been, to establish the value of disarmament in preventing war as contrasted with a gesture after its abandonment.

A great deal of effort was devoted at Washington to the new agencies of war, but in a very narrow sense. The general nature of the problem does not appear to have been recognised, and even in the long discussions on chemical warfare the issue was clouded by the old catchwords of " overnight conversation " and " low mortality." It is well known how the maximum result obtained was some measure of agreement to prohibit the use in war, but it is not generally appreciated why the matter was left in this helpless position. The reasons are summed up in the words of Mr. Balfour : " Their specialists had pointed out in Washington, and an examination by a Committee of the League of Nations had brought out a similar result at Geneva, that it was perfectly impossible so to arrange matters that a nation bent upon doing so should not in times of peace—whatever the rules of war might be—make such preparations as would enable it to use that monstrous and inhuman method of warfare at its will if war broke out."

It is of the utmost interest to us to try to ascertain why Mr. Balfour and the Conference had to adopt this hopeless outlook as the best and final expert opinion. The various points emerge in reading the discussion. M. Sarraut, for France, when rising to support the Root Resolution for prohibition of poison-gas, said that the reports of experts who had maturely considered the question had shown the extreme difficulty, if not impossibility, of taking practical precautions against the threat and the use of these chemical weapons. " It was an established and indisputable fact that those chemicals, which were used in the manufacture of gases and poisons, were the same that were used for innumerable ordinary substances necessary to the industrial and peaceful life of the human race.

" The reports of experts had established the impossibility of exercising an effective supervision over the production of gases

which might be used as weapons of war, and hence the impossibility of preventing or limiting such production. This entailed, as a logical consequence, the impossibility of preventing any country from arming itself in advance against the unfair use of those gases which an unscrupulous enemy might secretly prepare for sudden use upon an unprotected enemy, as had been done during the late war."

It also appears that the sub-committee of the Five Powers which had been appointed to consider the question had in their memorandum "more or less unanimously" agreed on certain points. These first emphasised the great importance of chemical warfare, and then claimed as follows. Research which may uncover new gases "cannot be prohibited, restricted, or supervised." The manufacture of any particular chemical warfare products cannot be restricted owing to the increasingly large peacetime use of several warfare gases. Again, the Committee dealt to a certain extent with the suggestion that gas might be a relatively humane weapon. These are the points, and this was the type of thought which effectively blocked positive disarmament measures on the new agencies of war.

One cannot avoid the conclusion that the whole matter was prejudiced by the ill-digested generalisations which have so often arisen in this subject, and which we have dealt with in previous chapters. I need hardly remind my readers, if they have followed my arguments and facts, that it is not only dangerous, but ludicrous, that the old claim of the merciful nature of the new agencies should have any weight in an important world conference. It must also be clear that the sweeping generalisation claiming the impossibility of control of production because some gases are also peacetime products should never have been left at that point, but much more thoroughly examined. The real position has been shown in our chapters on the new agencies, and we have seen that the value of disarmament would depend on a series of factors, of which the convertibility for war of small tonnages of a few existing products has only minor importance, and should never be allowed to govern the solution of the problem.

Again, the easy acceptance that nothing can be done on the matter of research can hardly be admitted in view of the results of our patient examination of the nature of such work. It was clearly not realised by the experts that they could only advise their Governments and the Conference as to the feasibility of

practical measures after a keen and detailed analysis of the process of armament evolution.

It is to be noted that Mr. Balfour referred to the fact that the same negative conclusions had been advanced by the Committee of the League of Nations in an examination prior to the Conference at Washington. It is therefore very interesting and important to ascertain what those activities at Geneva really were.

THE LEAGUE MEETING, BRUSSELS, 1920

Mr. Balfour was presumably referring to the report of the Permanent Advisory Commission for Military, Naval, and Air Questions to the Council of the League of Nations, made at the Brussels meeting in October 1920. I cannot find that the Committee sat with the general and essential terms of reference of examining the problem of the new agencies of war to ascertain whether any disarmament measures were possible, and to probe such measures. Four questions were put to the Committee for them to answer.

They were first asked whether the weapon was fundamentally cruel, and naturally replied, "Not more so than other methods commonly employed"; but "against non-combatants, barbarous and inexcusable." Secondly, in cases where the weapon is permitted, do the normal methods of quantity limitation apply? The short answer must be quoted in full as a prize example of negative results through insufficient exposure of the problem. The experts said: "It would be useless to seek to restrict the use of gases in wartime by prohibiting or limiting their manufacture in peacetime." No more confusing reply could have been given to any disarmament body. The fallacies are clear. They were governing the whole question of chemical disarmament by their answer on one of the possible measures, and in regard to the latter they merely said it was useless to seek a solution on the lines indicated. It is very puzzling as to why such an inconclusive answer should have been accepted as final.

The third and fourth questions at least permitted a constructive answer. Thus the third asked, Under prohibition, are there measures able to render it effective? Would it be possible, for example, to prohibit experiments, or to prevent the immediate adaptation of the products of commercial factories to military purposes? The answer given was simply that such measures were out of the question. Fourthly, they were asked to give the Council

an opinion in a general way concerning international regulations in this matter. This was the opportunity of the Commission to correct the dangerous effect of their answers to a series of badly framed questions, but they merely said it was a question of international law and "a problem for humanity," to which it was not their duty to supply an answer.

Here, therefore, we see complete omission to expose the essentials of the problems. The questions were not so framed as to compel exposure, although the last invited it, and the Commission was presumably not equipped, or empowered, or disposed to remedy the defect. Its general opportunity was side-tracked by ruling the fourth question as being outside its competence.

There was no mention of bulk chemical requiring many steps to become a weapon, no hint of the interlocking with normal armament through shell and gun, no reference to large testing-grounds, nor to the importance of protective types. Surely the real and constructive method, one which the world was entitled to expect, was an exposure of all such points on the lines of our study of "The New Agencies of War," at least a hint as to possible measures coupled, if necessary, with warnings as to risk. The measure of the latter, linked, if necessary, with grave warnings, was for the Council and the peoples, for they might find ways of reducing it.

The whole treatment exposed some common fallacies of disarmament thinking—to regard the risk of a scheme involving a number of partial measures as governed by that of one of them alone, or worse, to deny a scheme any value because one element of it may alone be thought to be inadequate. But this is entirely wrong. It is a problem of probability, in which the chances of a certain complex occurrence, the breakdown of a disarmament scheme, are only measured as a total of the risks of its component elements when the latter are entirely independent. But in our disarmament problem they exercise a check the one upon the other. When they interlock and have common relationships, the risk and the probability of evasion is very much reduced, and security acquires an altogether different magnitude.

In criticising the treatment of the subject at Geneva and Washington I do not claim that the most thorough exposure, in place of cryptic conclusions, would have led Mr. Balfour, and others since, to have changed their viewpoint. On this matter I invite the reader to form his own opinion, after considering the ideas thrown up in previous chapters, remembering that they are

simply the beginning of the study of this great issue, with a technical line of approach.

THE PREPARATORY COMMISSION, 1926

I cannot leave the subject without a short reference to the conclusions of the Preparatory Commission for the Disarmament Conference in 1926, the latest approach to a world in full disarmament conference. The report to the Council reveals a very long and detailed survey of disarmament in all military, naval, and air matters, and, as usual, took the form of answers to specific questions. A whole series was framed and answered in relation to chemical warfare. We are most interested in the last of these, which invited Sub-Commission A "to consider what effective sanctions can be proposed for the enforcement of the international undertaking not to employ poisonous gas or bacteria in warfare."

Various Delegations replied, but the general conclusion was as follows. Constructive measures are impossible ; there is no technical means of preventing chemical warfare ; and the only practicable measure is organised reprisals. Certain countries refused to associate themselves with the latter, because it was political and not technical, but in this refusal the German Delegation took up what appears to be the most logical position. They submitted that they were "ready to agree without any reservation to any international rules for the purpose of abolishing chemical warfare," but "any measures must be avoided which are calculated, even in the form of sanctions, to make chemical warfare general," "a form of warfare laid down as a sanction, and recognised by international law." This was obvious, for the solemn suggestion to be organised for reprisals simply meant the old argument "arming to disarm," an amazing conclusion for a disarmament body of this importance.

Now let us see on what kind of evidence the somewhat hopeless conclusions of the other delegations were based. There were questions as to the time of convertibility of chemical factories. No real analysis was made in terms of old or new gases, no examination as to the bearing of quantity necessary to make violation effective or worth while, and no adequate reference to the other substantial interlocking elements of time lag, factors for security. One official answer suggested that factories could be immediately adapted, another said that only a few hours to a few

weeks were necessary to manufacture and make use of the products in warfare, and, again, "artillery shell and similar projectiles for gas would take several weeks to make."

One sees a number of statements which could find no support whatsoever in the history of armament production and development up to date, even under the excessive speeds of the war itself. It is a serious question whether there was really any proper examination of the technical details of the subject before these very damaging and blocking generalisations were brought forward. Did anyone take the elementary precaution to examine the records of armament production, as we have done in support of our conclusions? There is only one proper method of procedure, and negligence in this and in consequent action will involve the gravest censure from future generations, especially if a war which might have been avoided by disarmament is inflicted upon them.

CONCLUSION

Criticism is easy, and one hesitates to apply it to the patient efforts in the official movement towards disarmament. But there is one very strong, valid, and constructive criticism which can be made without regret, because it is implied, almost self-imposed, at many points in the long chain of official records. Time after time we find important conferences failing and breaking up on the note that further technical investigation on disarmament is required. It may be that at Geneva or in some national Government the systematic exploration of the field is going on, but the poverty of results would certainly lead an expectant world to conclude that in ten years of work the search has been inadequate.

There are two obstacles to world disarmament: the inheritance of the past and the failings of the present broadly classified under political difficulties, and, secondly, the total absence of any reasoned scheme which might satisfy the dual needs of effective disarmament and retention of national security. We have fluctuated like a pendulum, with much waste of time and effort, between the two problems, political and technical; at one time giving the former precedence and at others the latter. Sometimes the slogan has been "Security, then disarmament" and at others, but rarely, "Disarmament first." The recent Italian answer to the proposed European Federation is "First disarm."

But neither viewpoint is correct. There is a position of minimum

difficulty for world disarmament, minimum friction, need of compromise, loss of time, and this position coincides with the most complete exploration and rational solution of the problem of technical disarmament. Presumably we shall never entirely eliminate political difficulties ; they will always arise to confuse the disarmament problem ; but at any given stage they will approach their minimum effect as disarmament reaches its maximum technical value, as it becomes a positive element in security instead of a gesture when safety has been attained. In fact, it would not be too much to claim that the oft-repeated "Safety first, disarmament next" is an impossible method, because the former cannot be attained without the latter, and they must progress side by side.

We know that the final steps in any field of disarmament will always be difficult. Nations are still hanging on to the top-heavy raft of armament. They know that they have no real general security by this means, but they are afraid to take the plunge, and they are entitled to measure their new risk, whatever the past one may have been. The more we can reduce this risk the better the chances become. The more we can present them with a sea-worthy alternative, the readier they will be to abandon their insecure but accustomed craft.

Taking only two examples, it is perfectly clear that the official advice and assistance which have so far been put forward for international consideration on the private armament industry and on chemical warfare are insufficient to justify abandoning the old activities, but it must be clear from the previous chapters that the facts of the case permit the assumption that really competent examination of these matters leads to the possibility of valuable and effective disarmament measures.

To the extent that weight can be attached to the facts and conclusions which we have put forward, so it might be thought that they constitute a criticism of disarmament efforts up to the present where these appear inadequate. But we have far too much appreciation of the difficulties of reaching international agreement on such matters to come forward as critics. If the official world adopts the budgetary system, practically ignores the theoretical requirements of direct limitation, and does nothing on the acute problem of the development of new armament types, the real viewpoint to adopt is that what has been done is extremely valuable as a move in the right direction so long as it is realised that further action must be taken. On this, the question

of the future, reasoned criticism can only be helpful. Here we are fully entitled to conclude as follows.

We need somehow to start systematically at the point and in the direction that was clearly intended after the disarmament of Germany. We must give the League organisation a proper, uninterrupted, and unbiased opportunity to study its subject just as though it were a technical matter, completely excluding for a time all the political and narrower issues which admittedly will finally thrust themselves into the arena.

What are the subjects which the League must study? Has it competent personnel for the purpose? Does it need fortifying or regrouping? Has it the information it requires? These questions must be faced, and the answers given effect to with the necessary authority and assistance. Further, it would be wise for the Great Powers to regard the subject of disarmament as one in which they are intimately and constructively concerned, and not simply as easy critics of measures thrown up by a central organisation, ever governed by the thought as to whether its proposals are likely to hurt the feelings or prejudice the interests of this party or the other. A department or commission for the investigation of international disarmament in the national organisation of a Great Power is a necessary and entirely logical step. If this book contributes in the slightest degree towards the organisation of the systematic study of this great subject it will have served its purpose a hundred times over.

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